Overview of LLNL Services and Tools for the National Atmospheric Release Advisory Center (NARAC) and Interagency Modeling and Atmospheric Assessment Center (IMAAC)

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University of California
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NARAC-IMAAC Can Provide Predictions for Assessing a Wide Range of Atmospheric Hazards

- Explosive dispersal of radiological material
- Nuclear explosions
- Toxic industrial chemical spills
- Fires
- Biological agents
- Chemical agents
- Nuclear power plant accidents

What is the hazard?
Where is it going?
Who is at risk?
How do we respond?

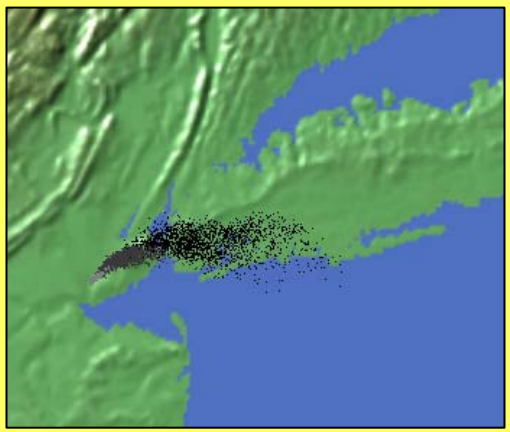
NARAC-IMAAC Provides Consequence Management Tools, Services & Products

Event information

- Weather data
- Nuclear, radiological, chemical, biological source information
- Sensor data

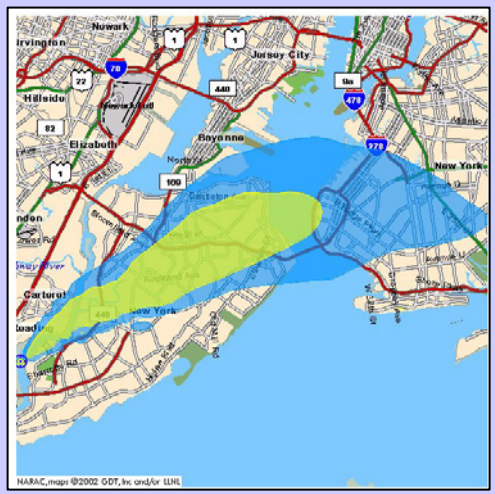
Plume Models and Expertise

- Advanced, automated 3-D plume modeling anywhere in real-time
- Scientific and technical staff provides training/assistance and detailed analysis 24 hrs x 7 days

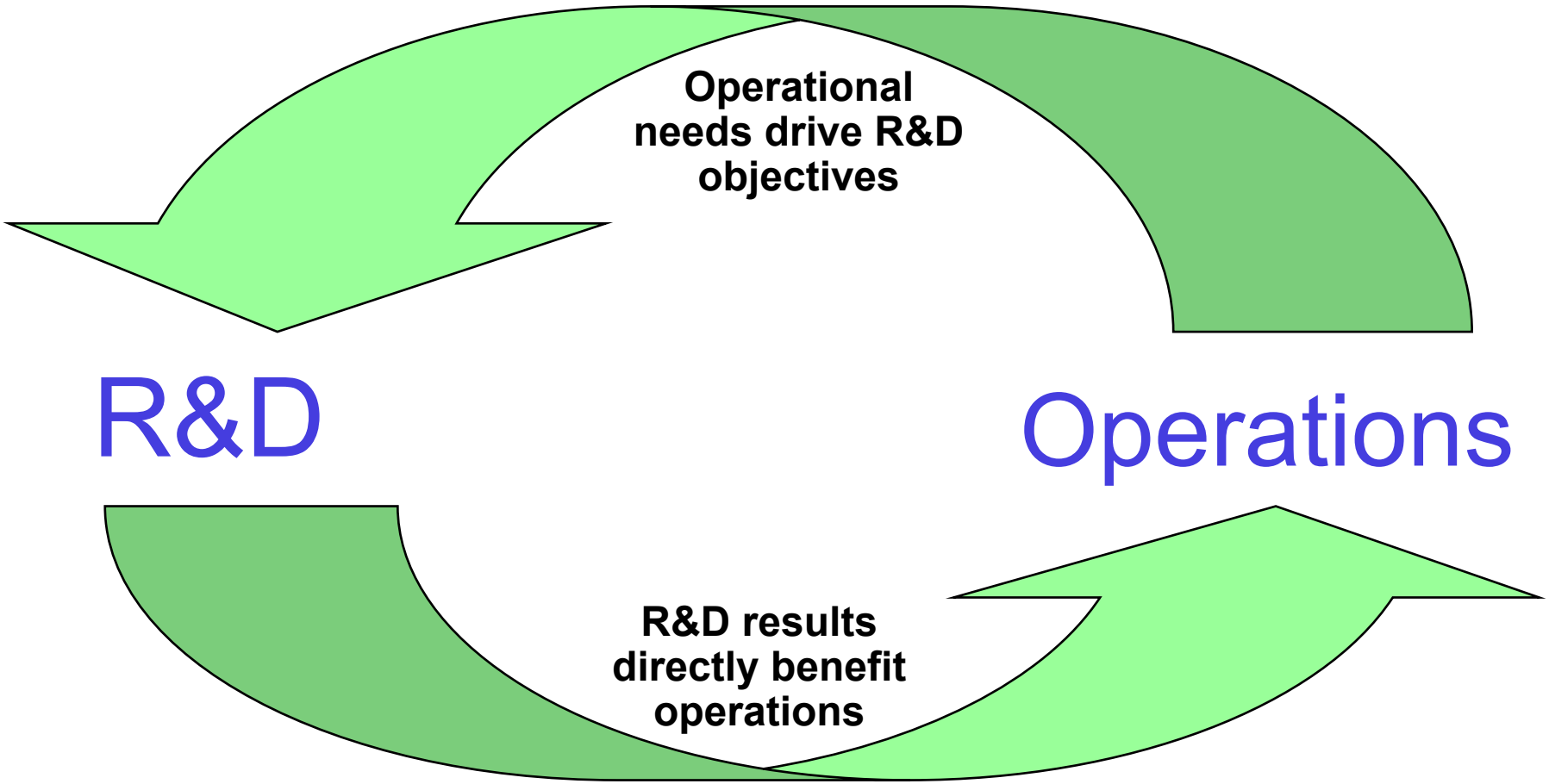


Incident Management Information

- Health effects, exposed population and facilities
- Casualty/fatality/damage estimates
- Response strategies
- Protective action recommendations
- Geographical information



NARAC-IMAAC Benefits from a Tight Coupling of R&D and Operations



Multi-organization collaborations benefit both R&D and Operations

NARAC/IMAAC Program Functional Organization

NARAC/IMAAC Program

Gayle Sugiyama, Program Leader (PL)

John Nasstrom
Operations Center Associate PL

Roger Aines
S&T Associate PL

Pam Drumtra, Administrator
Cheryl Pearson, Resource Analyst
Lourdes Placeres, Admin. Assistant

Operations Team

Ron Baskett (Response & Outreach)
Brenda Pobanz (Software Integration)

- **10 M.S./Ph.D. scientists provide plume modeling support for training, planning, exercise, emergencies and assessments**
- **3 technicians provide customer help-desk support**

Hardware and Software System Team
Shawn Larsen (Systems development)
Bill Eme (Customer interface software)

- **17 scientists, engineers and technicians maintain and develop systems**
  - **Servers and communications links**
  - **External user access (iClient/Web) software**
  - **Central modeling system software**

Modeling/R&D Team

Gwen Loosmore (Model integration)
Branko Kosovic (R&D)

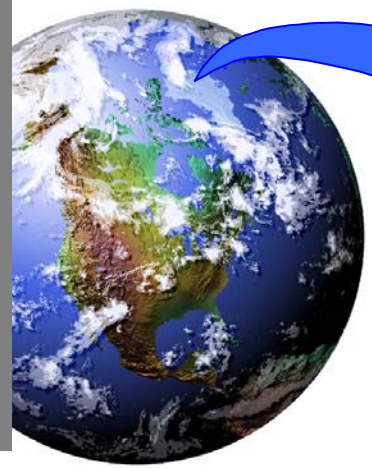
- **19 Ph.D./M.S. scientists and engineers develop and validate atmospheric flow and transport models**

National Atmospheric Release Advisory Center (NARAC)

Real-time Weather Data, Plume Model Predictions and Expertise

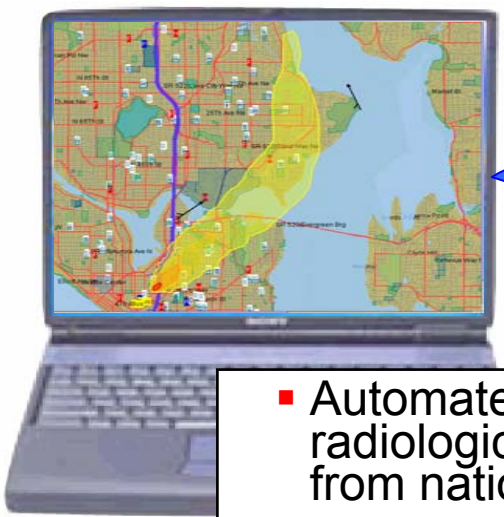
Access to world-wide weather data and geographical information:

- Observed & forecast weather data
- Terrain & land surface
- Maps
- Population



National Atmospheric Release Advisory Center (NARAC):

- Computer systems for 3-D plume simulations
- Un-interruptible, backup power
- 24x7 scientific & technical support



- Automated real-time 3-D plume model predictions for nuclear, radiological, chemical or biological releases available in minutes from national center using Internet/Web tools
- Standalone simple plume modeling tools for end-user's computer require no connection to NARAC

NARAC-IMAAC Operational Services

- **24x7 on-duty or on-call expert scientific staff** to support planning (including National Security Special Events), assessments, emergency response, recovery, post-event analyses
- **Regular exercises** with individual sites, cities, regional & national response teams, national-level exercises (e.g., TOPOFF top officials series)
- **Communication links** to meteorological data and customers using Internet- and DOE intranet (ECN), SIPRNet, other classified, satellite, dial-up and wireless
- **Maintain readiness of NARAC facility** and computer systems (unclassified and classified) with un-interruptible and backup power supply and 24x7 on-call technicians/engineers
- **Customer technical support services** (help desk) for end-user tools
- **User training** courses and materials

LLNL/NARAC-IMAAC supports over 6000 tests, drills, exercises, alerts, and emergencies per year

LLNL has a 27 year record of timely and accurate multi-hazard atmospheric release assessments

1973 DOE R&D Program

1979 ARAC Operational Center established

Generation-2 system (nuclear/radiological)

DOE site support for toxic industrial chemicals

DOE CBNP program

1996 DOE NARAC facility dedicated

Generation-3 system (CBRN)

2002 LINC program

2003 DHS S&T

2004 DHS interim IMAAC established

1980

1985

1990

1995

2000

2005

Selected Events

1979 Three Mile Island reactor leak

1980 Titan Missile explosion AK

1980 China atmospheric nuclear tests

1986 Chernobyl reactor accident

1991 Kuwaiti oil field fires

1993 Richmond, CA refinery fire

1997 Cassini satellite launch

1998 Tracy tire dump fire

1999 Tokaimura, Japan, criticality accident

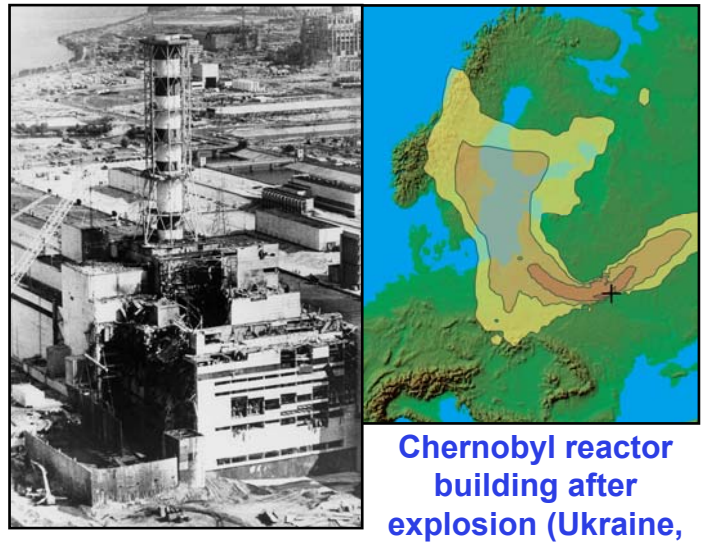
2001 September 11

2003 Staten Island oil barge fire

2003-2004 New Years Orange Alert

2004 Conyers, GA chemical fire

2006 Pluto New Horizons spacecraft launch



Chernobyl reactor building after explosion (Ukraine, 1986) and LLNL plume prediction

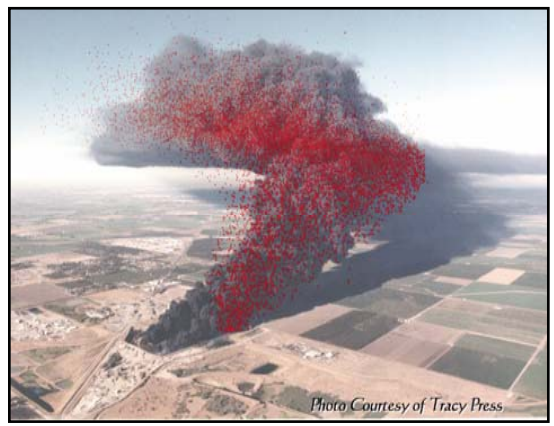


Photo of smoke from tire dump fire (Tracy, California,1998) with plume prediction in red

NARAC-IMAAC Program Sponsors

- DOE NA-40 Emergency Operations — Atmospheric Release Advisory Capability (ARAC) Program
- DHS S&T — Interagency Modeling and Atmospheric Assessment Center (IMAAC), Urban and CB Plume Modeling Research and Development, Local Integration of NARAC with Cities (LINC) demonstration project
- DOD/DOE Naval Reactor sites emergency response
- DOE NA-23 Office of International Emergency Management and Cooperation — International nuclear emergency response
- Other LLNL/NHI projects for DOE, DHS, and DOD

Interagency Modeling and Atmospheric Assessment Center — IMAAC

- Under DHS leadership, IMAAC coordinates dispersion modeling for atmospheric chemical/biological/nuclear hazard predictions among federal agencies
- MOU signed by 7 federal agencies: DHS, DOC/NOAA, DOD, DOE, EPA, NASA, and NRC
- IMAAC roles are codified in *National Response Plan* (NRP) and *National Exercise Program* (NEP) for Incidents of National Significance
- NARAC has been designated the primary initial provider of IMAAC capabilities
- Interagency working groups are developing Standard Operating Procedures (SOPs). Agency-specific MOU annexes are being written

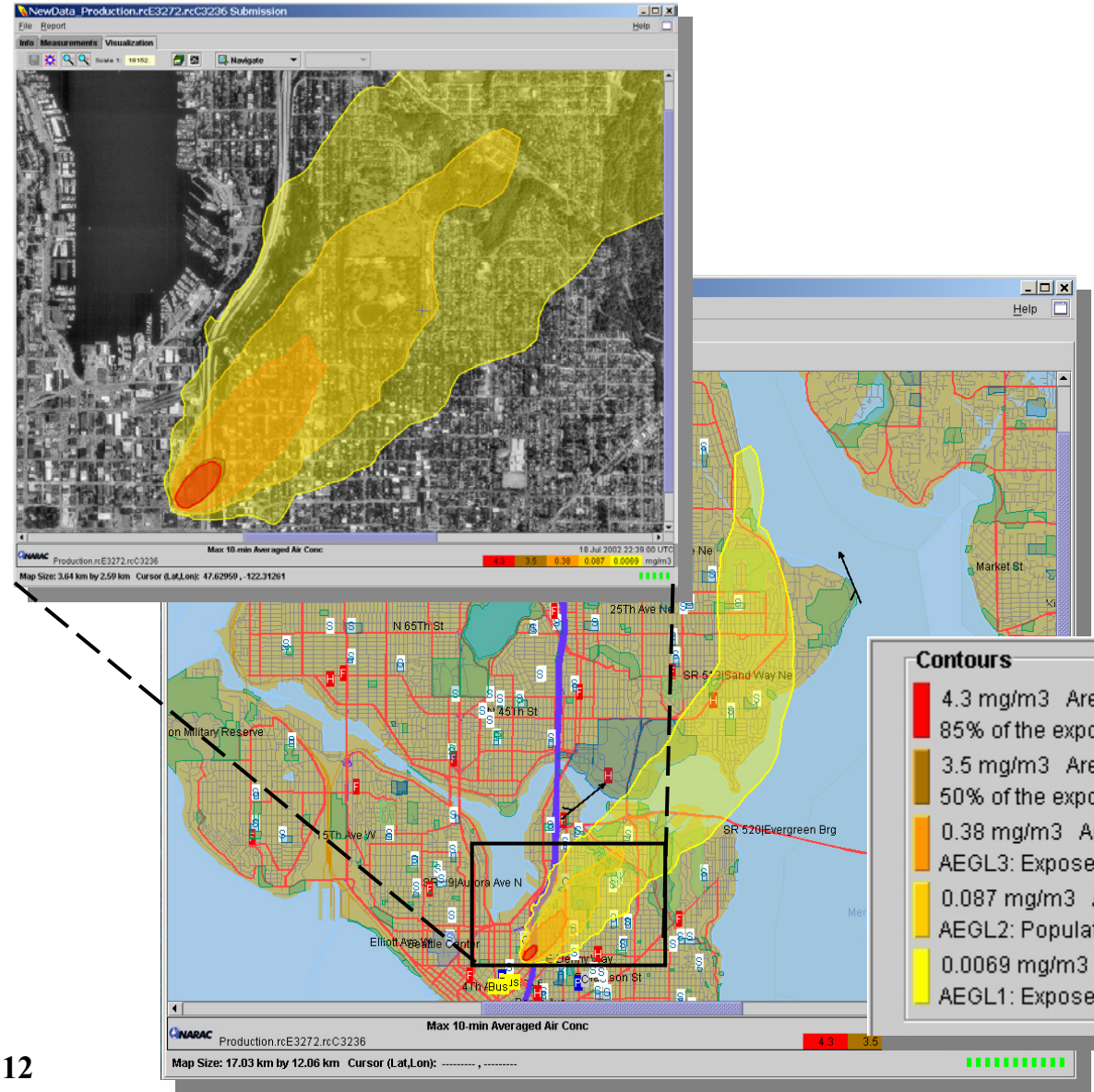
"IMAAC provides a single point for the coordination and dissemination of Federal dispersion modeling and hazard prediction products that represent the Federal position during actual or potential incidents requiring Federal coordination"
National Response Plan, May 2006

LLNL Works Closely with Many Organizations to Provide Integrated Emergency Response Support

- **DOE National, Regional Operations Centers and Response Teams** — Headquarters and regional EOCs, RAP, ARG, RAP, NRAT, JTOT, CM/FRMAC, AMS, Triage, REAC
- **DHS National and Regional Operations Centers and Response Teams** — HSOC, FEMA NRCC and RRCCs, TSOC, WMDO-IM, and USCG, USSS
- **Federal, Interagency Response Centers and Teams** — IMAAC (includes DHS, DOD, DOE, EPA, NASA, NRC), FRMAC (with DOE and EPA), Federal Advisory Team for Environment, Food and Health (includes EPA, USDA and HHS)
- **40 Nuclear Sites** — DOE sites, Naval Reactor sites, and DoD Sites
- **LLNL centers of chemical, biological and nuclear expertise** — Biological Defense Knowledge Center, NSTTAR, NAP, Forensic Science Center
- **DOE NA-23 Office of International Emergency Management and Cooperation —** Foreign countries and international organizations (IAEA)
- **DOD National Operations Center and Teams** — USNORTHCOM, DTRA, National Guard, Air Force Weather Agency, Navy's Fleet Numerical Meteorological and Oceanographic Center
- **NRC National and Regional Operations Centers and Response Teams**
- **EPA Operations Centers and Regional Response Teams** and On-Scene Coordinators
- **NOAA National Centers and Teams** — Hazardous Material Response Division, National Centers for Environmental Prediction (NCEP), regional Weather Forecast Offices, Incident Meteorologists
- **National Laboratories —** Sandia, Remote Sensing Laboratory, Lawrence Berkeley, Argonne, Oak Ridge, Los Alamos, Pacific Northwest
- **NASA** — Kennedy Space Center
- **22 State organizations —** Operations Centers and Teams**,** emergency management, health and environmental agencies
- **Local** emergency management, fire, health, environmental, and police organizations (including 5 LINC pilot cities)

LLNL supports over 300 collaborating local, state, and federal agencies and emergency operations centers, with over 1700 on-line users

NARAC-IMAAC Predictions Provide Key Information for Emergency Decisions



- Plume hazard areas with potential health effects
- Protective action guides (e.g. sheltering, evacuation)
- Affected population counts
- Geographical information (transportation, facilities)

Contours

4.3 mg/m3 Area: 0.038 sq km Population: 30
85% of the exposed population could receive a lethal dose.

3.5 mg/m3 Area: 0.046 sq km Population: 30
50% of the exposed population could receive a lethal dose.

0.38 mg/m3 Area: 0.378 sq km Population: 3356
AEGL3: Exposed population could experience life-threatening effects.

0.087 mg/m3 Area: 1.450 sq km Population: 7482
AEGL2: Population could experience serious long-lasting effects.

0.0069 mg/m3 Area: 15.249 sq km Population: 33001
AEGL1: Exposed population could experience notable discomfort.

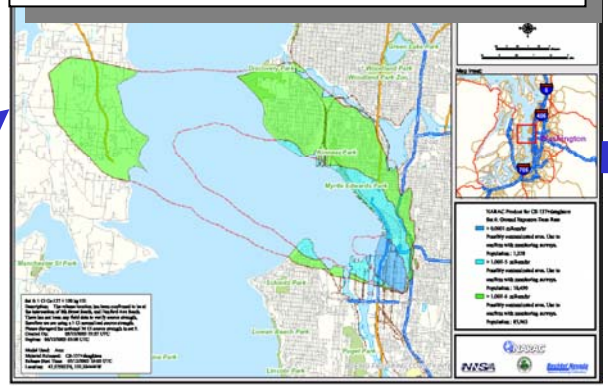
Benefits NARAC-IMAAC Products

Information and tools for…

- Situation awareness of current and forecast plume transport direction and hazard areas
- Determining safe approach and evacuation routing and incident command site selection
- Personal protective equipment use decisions
- Guiding field measurement and sampling teams
- Evacuation, sheltering and relocation decisions
- Communicating to the public (and allaying concerns)
- Impacted emergency response and health services facilities
- Estimating number of casualties and illnesses for hospitals
- Projecting areas were agricultural crops are contaminated

We Use Modeling and Monitoring in a Coupled, Cyclical Process

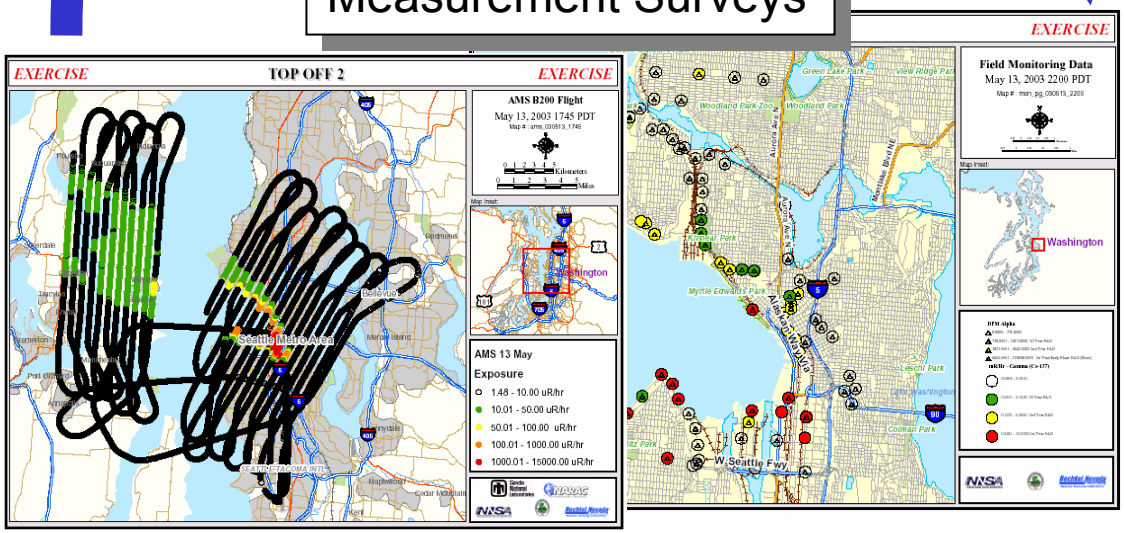
Plume Model Predictions



Model predictions guide measurement surveys

Measurements refine model predictions

Measurement Surveys



Examples from TOPOFF2 Exercise, in which NARAC worked with DOE/NNSA and interagency teams as part of the Federal Radiological Monitoring and Assessment Center

Integrated Modeling Capabilities Include In-House and Externally Built Models

Model	Source	Description
ADAPT	LLNL	Diagnostic meteorological model
BLAST	SNL	Pressure effects model for high explosives and RDDs
COAMPS	NRL/LLNL	Mesoscale forecast model
EPICODE		Gaussian plume model with hazardous chemical databases
GridGen	LLNL	Grid generation software for ADAPT/LODI using terrain data
Hotspot	LLNL	Gaussian plume model for radioactive and nuclear material
KDFOC	LLNL	Gross fission products fallout effects model
LODI	LLNL	Lagrangian stochastic particle dispersion model
NUKE	SNL	Prompt dose, thermal, and overpressure effects model for nuclear weapon
UDM*	DSTL	Empirical urban model
FEM3MP/ AUDIM*	LLNL	Multiprocessor computational fluid dynamics (CFD) building-resolving model

* Integration in progress

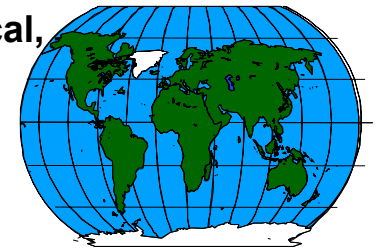
Collaborations Provide Additional Models & Data

Stand-Alone Models from Collaborations		
Model	**Source**	**Description**
CAMEO/ ALOHA	NOAA/ EPA	Gaussian plume model with toxic industrial chemical databases
HPAC	DTRA	Plume modeling system with SCIPUFF
RASCAL	NRC	Radiological source terms and Gaussian plume/puff model for nuclear power plant releases
Turbo FRMAC	SNL	Radiological dose calculations from air and ground contamination

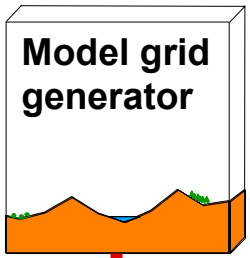
Forecast Model Results from External Sources		
Agency	**Model**	**Resolution/Coverage**
Air Force Weather Agency (AFWA)	MM5	45 and 15 km resolution, special regional forecasts
Fleet Numerical Meteorology and Oceanography Center (FNMOC)	NOGAPS 4.0	1° resolution, global
	COAMPS	Special regional forecasts
National Weather Service (NWS)	ETA	40 km and 12 km resolution, US
	GFS (AVN)	0.5° and 1° resolution, global
	RUC	20 km resolution, US

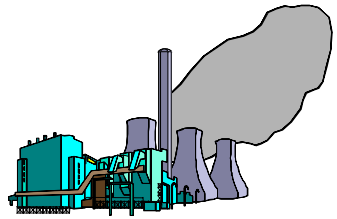
NARAC Central Modeling System Provides 3-D Plume Model Predictions

Geographical, Terrain Elevation, Population Databases



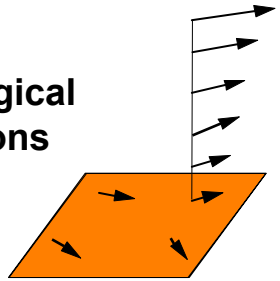
Model grid generator



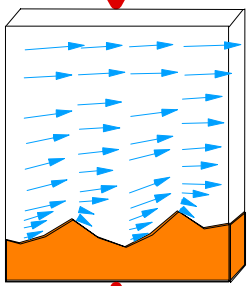


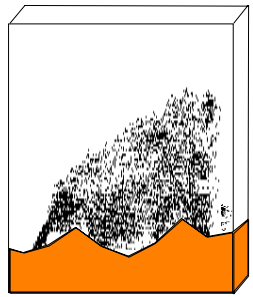
Source characteristics

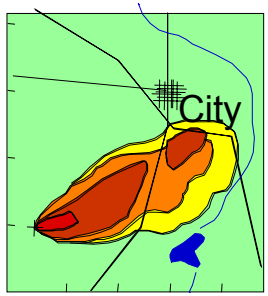
Meteorological Observations



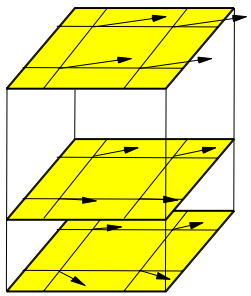
Data assimilation model (ADAPT)



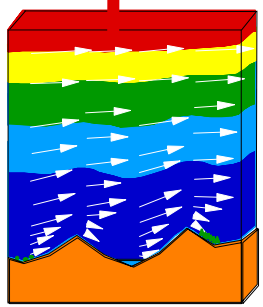




Large-scale forecast models (Navy, NWS)



Regional Forecast Model (Navy COAMPS)



Lagrangian Operational Dispersion Integrator (LODI)

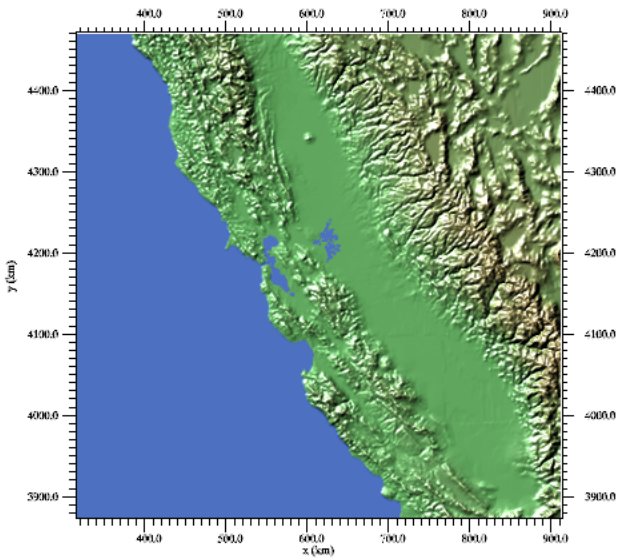
Air and ground contamination, Dose, Protective Actions Guidelines, acute health effects

NARAC's modeling system is fully automated and works for any location in the world in real-time

Source Characterization Models for NARAC/IMAAC Plume Model Predictions

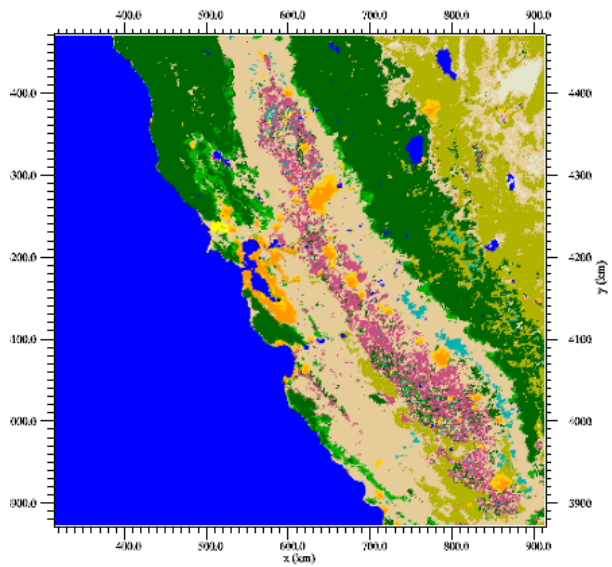
- Explosive dispersal devices: airborne fractions, particle-size distribution (SNL Source Term Calculator)
- Chemical and biological sprayers (SNL)
- Toxic industrial chemicals (leaks, spills, tanks) (EPA/NOAA)
- Explosive prompt blast effects prediction (SNL *BLAST* model)
- Buoyant & momentum plume rise from fires or stack emission (LLNL *LODI* model)
- Nuclear power plant release characteristics (NRC *RASCAL* model)
- Nuclear detonation cloud (LLNL *KDFOC* model)

Geographic and Population Data are Used in NARAC-IMAAC Models and Products



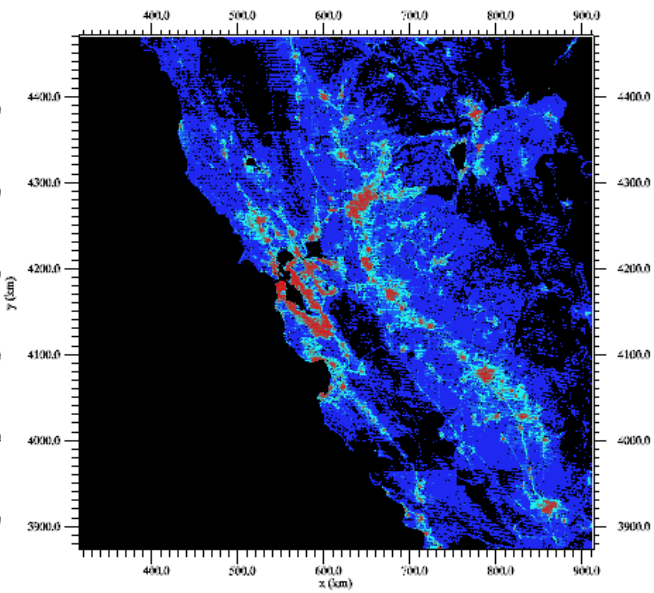
Terrain Elevation **is used for lower boundary of 3-D Meteorological flow and dispersion models**

- Global coverage
  - NGDC 10km
  - USGS 1km
  - NIMA DTED (1km, 100m, and 30m)
- U.S. coverage
  - USGS DEM 30m



Urban and Rural Land Characteristics **are used to model their effects on wind and turbulence**

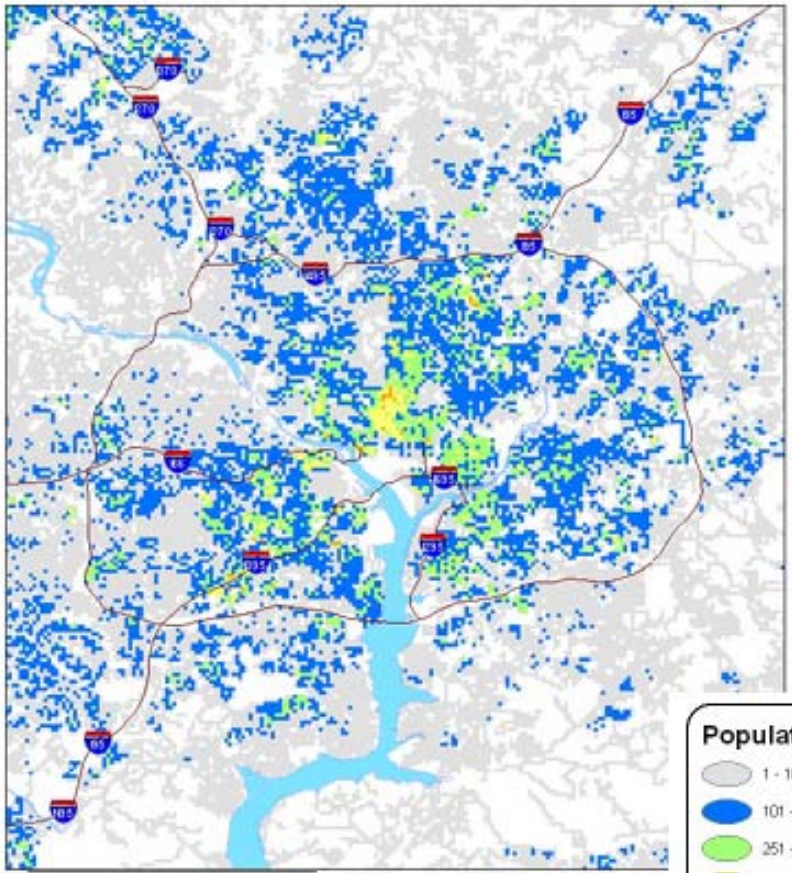
- Global coverage
  - GLCC, ORNL Landscan 1km
- U.S. coverage
  - USGS 200m LULC
  - USGS 30m NLCD

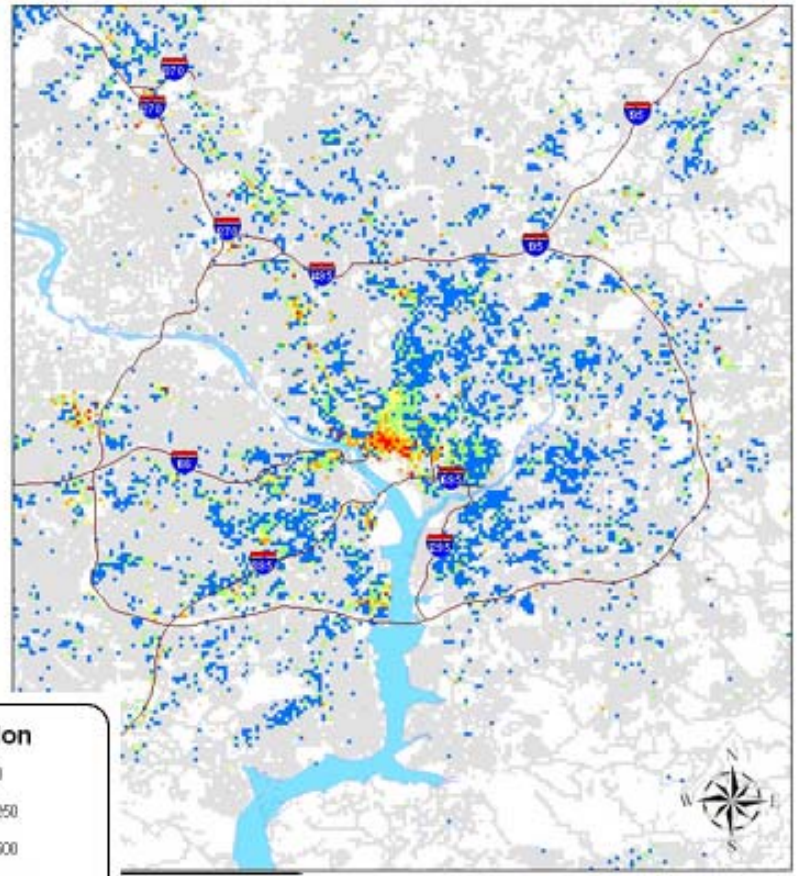


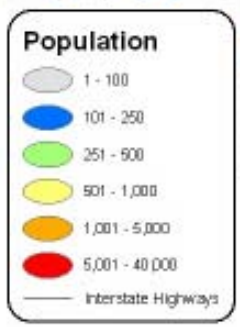
Population Density **data is used to estimate the population affected by the plume**

- Global coverage
  - ORNL 1km LandScan
- U.S. coverage
  - Census Bureau
  - LANL day-night variation

LANL Day/Night Population Database Washington DC Example



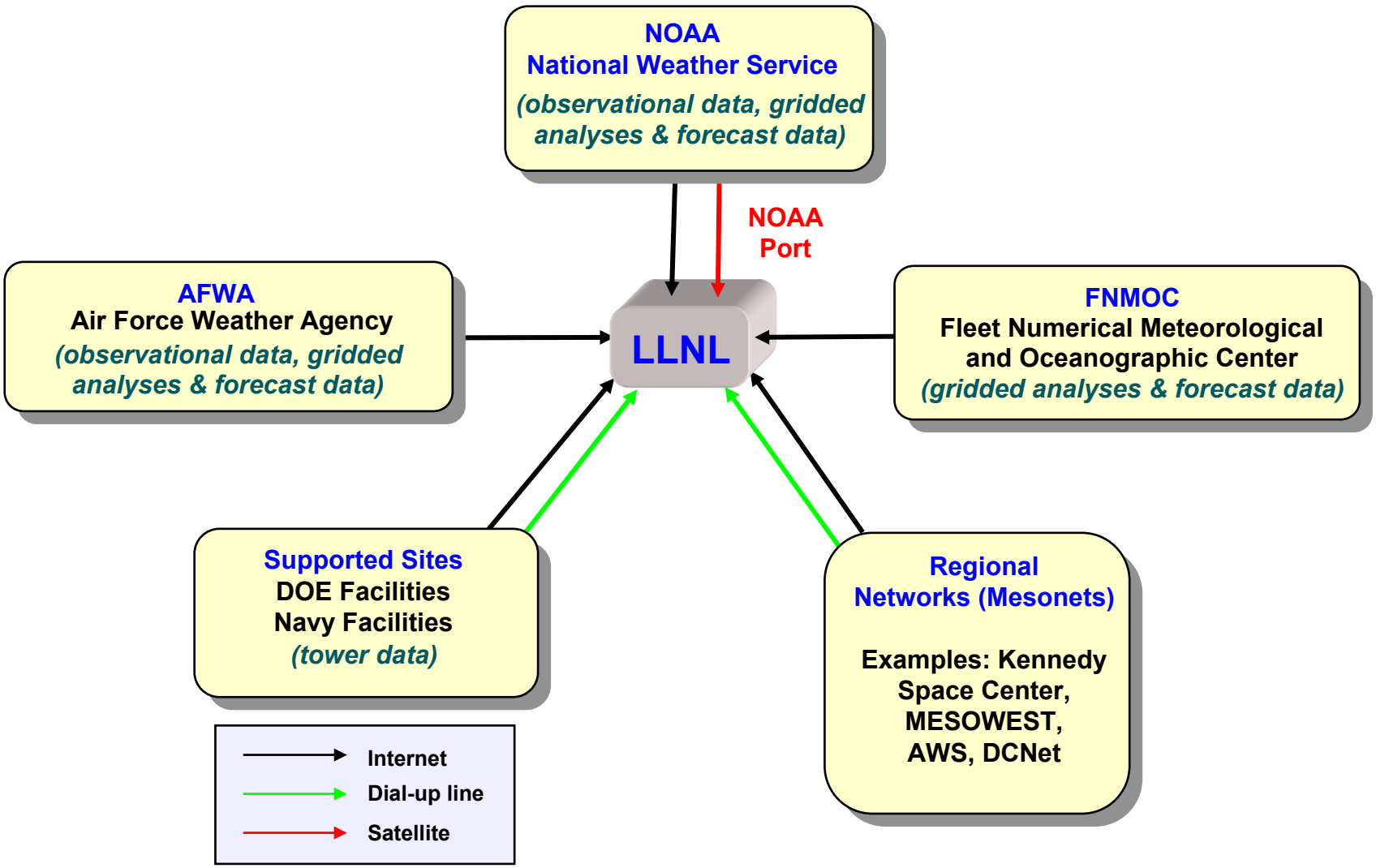




Night-time Population

Day-time Population

Redundant Weather Services Provide Automated Meteorological Data

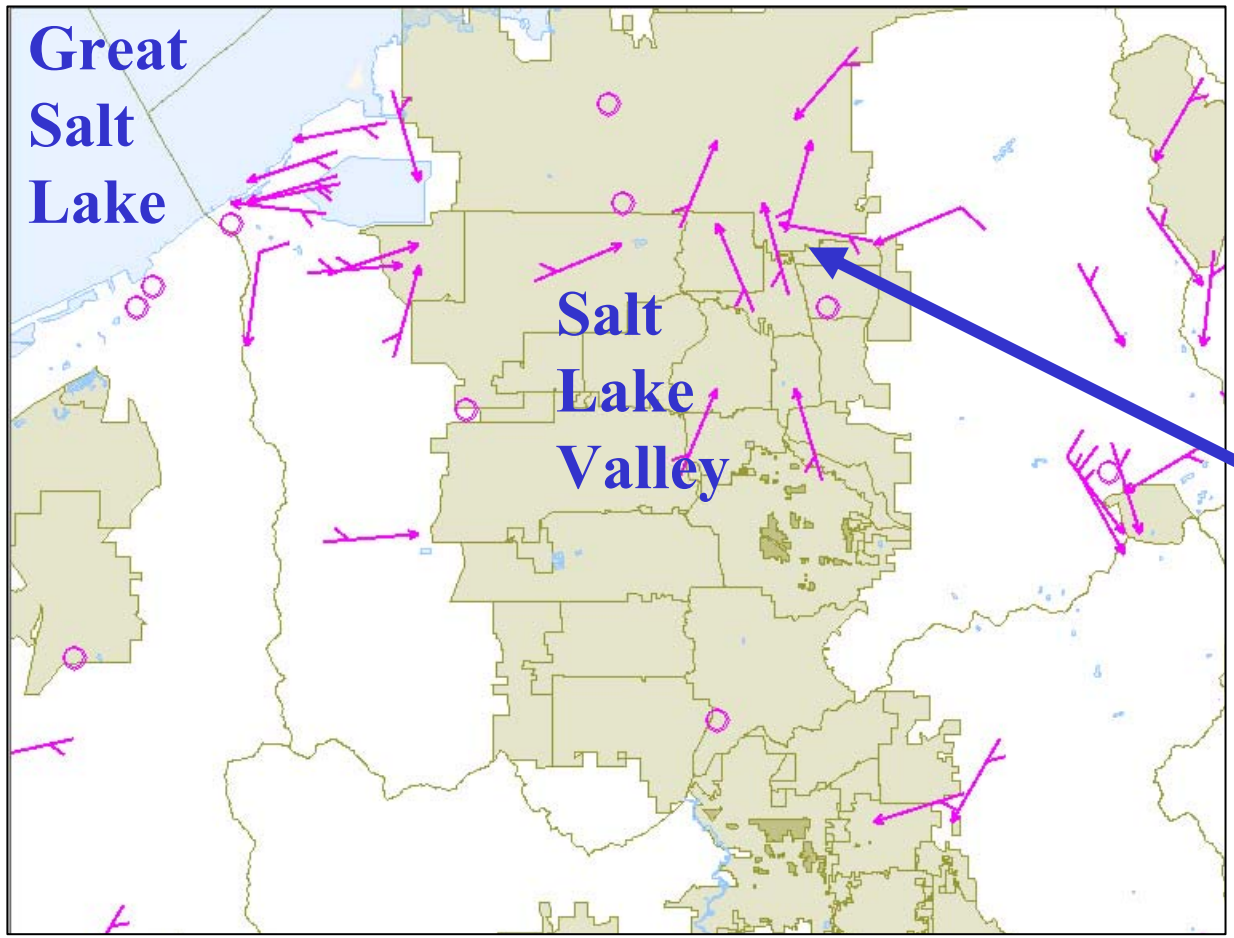


Meteorological Data Acquisition

- Over one million meteorological observations per day from around the world are collected and stored by NARAC
- Weather forecast model predictions from global and regional models are continuously collected from the U.S. National Weather Service and the U.S. Navy
- Special meteorological observation networks supplement global and regional data collected routinely by NARAC
- NARAC meteorologists analyze quality of data
- Users can view maps and tables of wind data

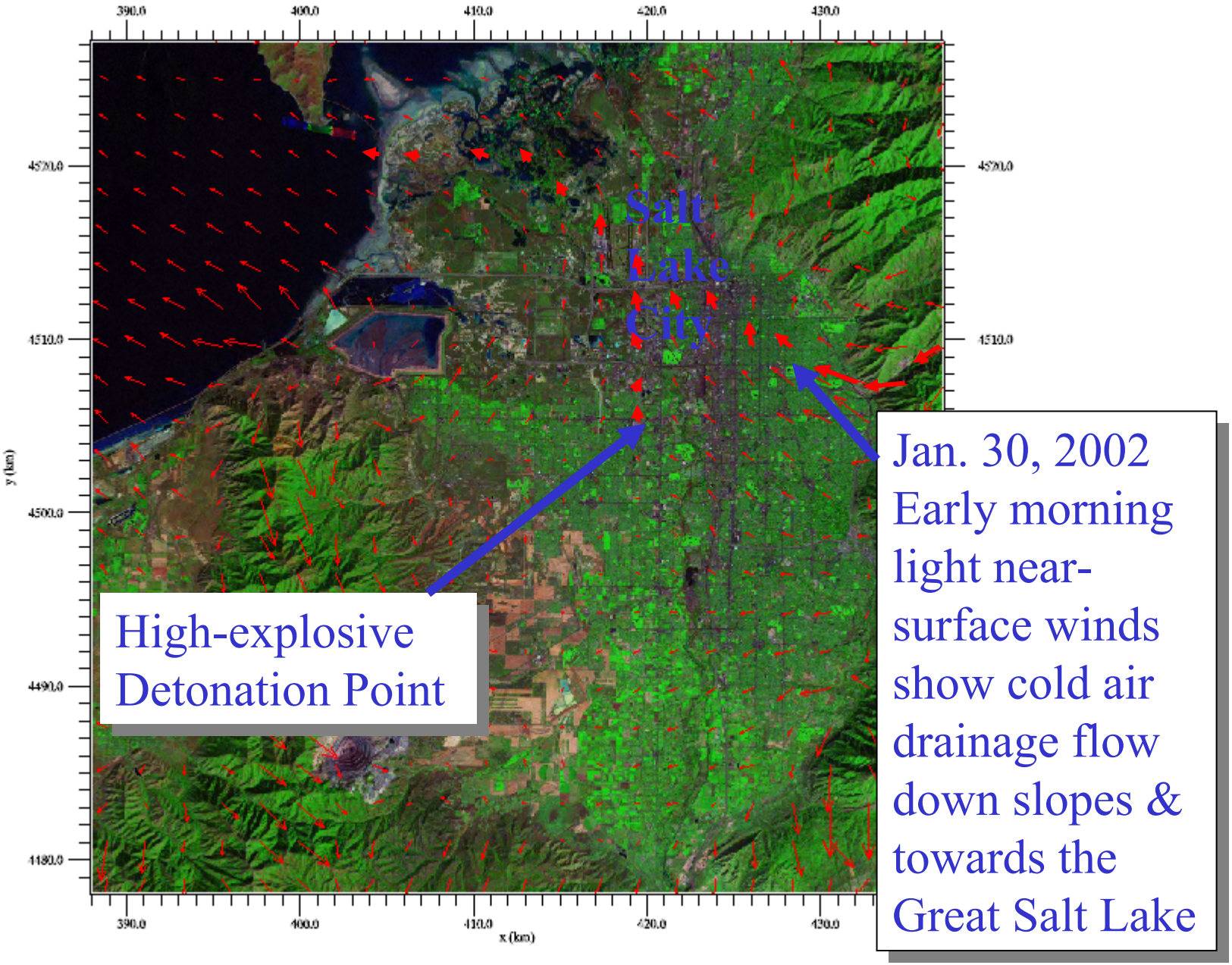
Case Study: Hypothetical RDD in Salt Lake City

Mesonet Surface Wind Observations

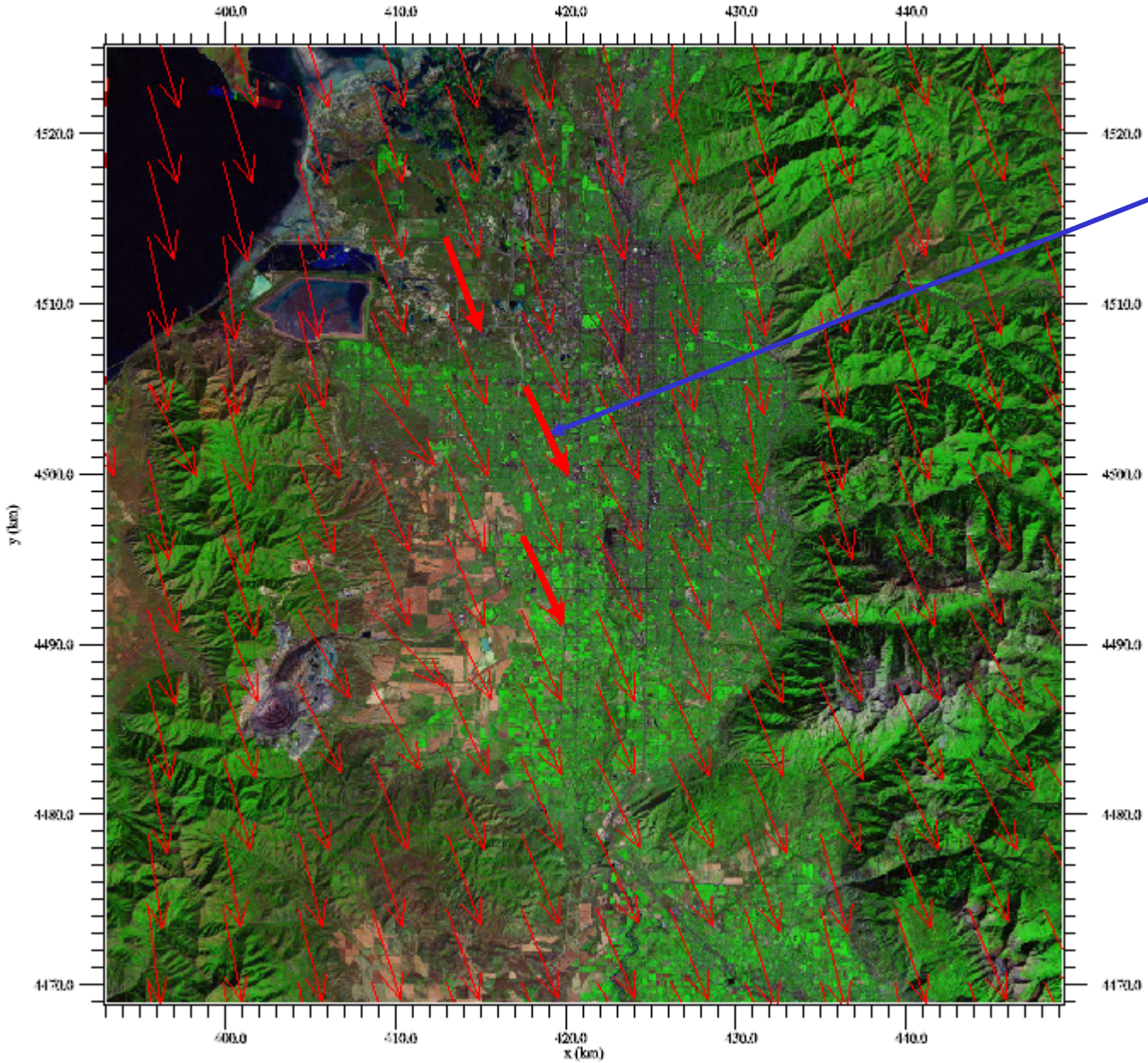


Jan. 30, 2002
Early morning light near-surface winds show cold air drainage flow down slopes & towards the Great Salt Lake

Case Study: Hypothetical RDD in Salt Lake City — NARAC ADAPT 3-D Model Surface Winds

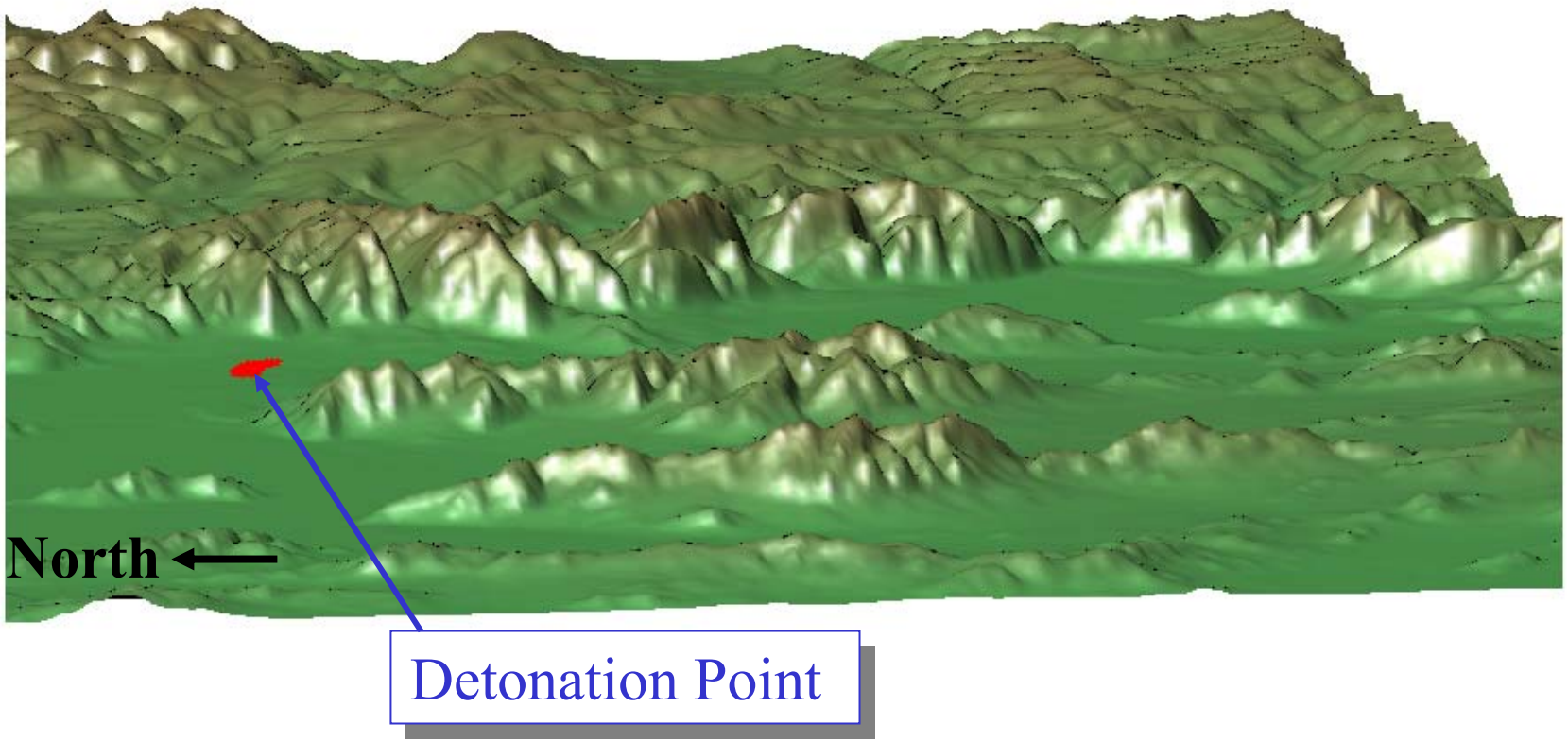


Case Study: Hypothetical RDD in Salt Lake City — NARAC ADAPT 3-D Model Upper-level Winds



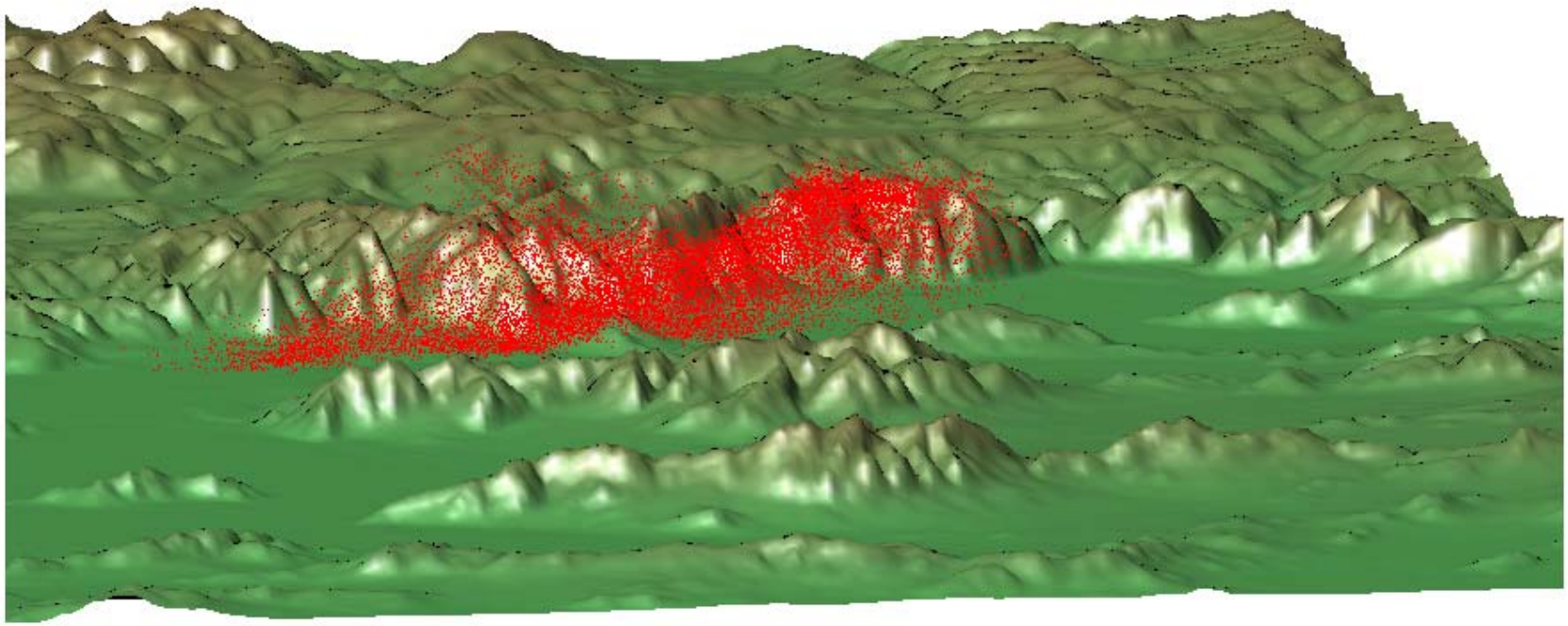
Stronger Upper-level winds from the north

Case Study: Hypothetical RDD in Salt Lake City — NARAC LODI 3-D Model Particle Dispersion Simulation

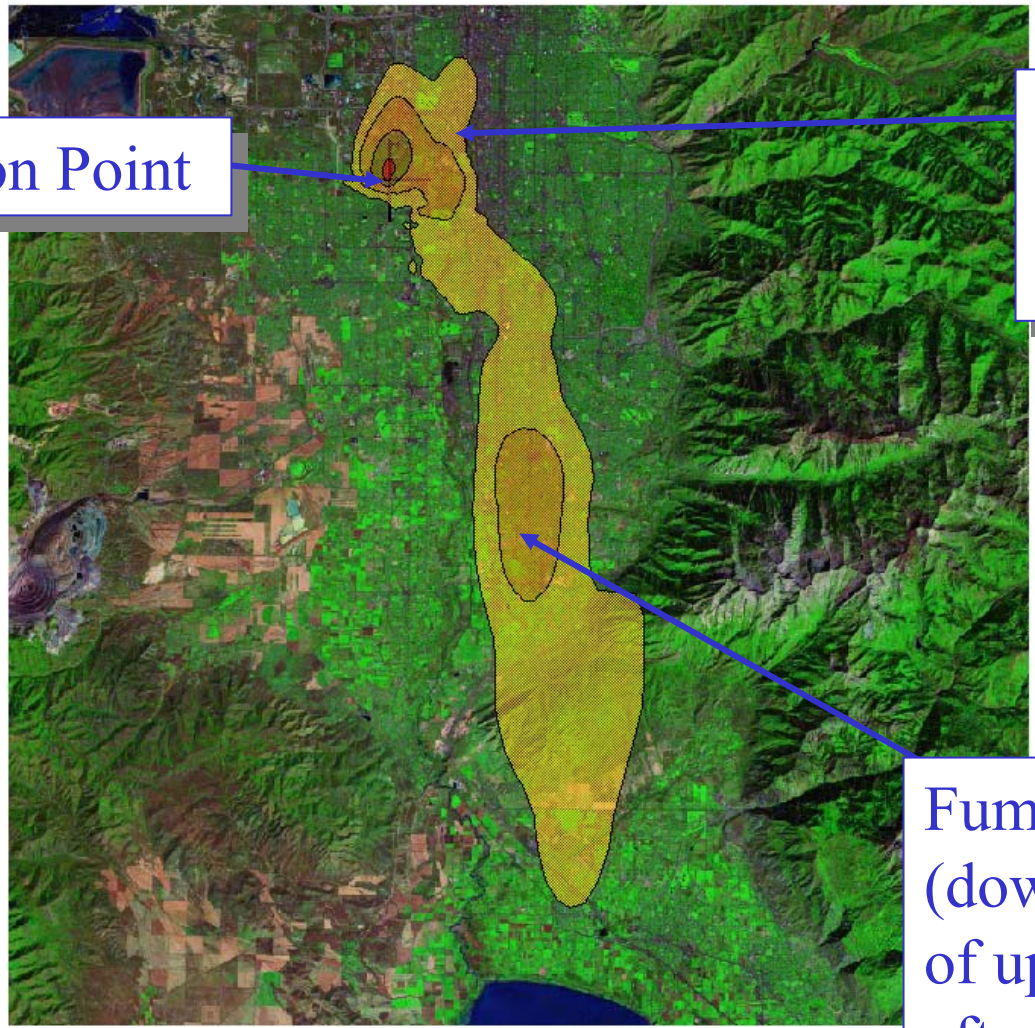


Red particles show LLNL NARAC ADAPT/LODI dispersion simulation using SNL ERAD explosive source characteristics (particle size distribution and spatial distribution of mass from surface to several hundred meters above ground) — Simulation begins at 05:00 MST (ends at 11:00 MST)

Case Study: Hypothetical RDD in Salt Lake City — NARAC LODI 3-D Model Particle Dispersion Simulation



Case Study: Hypothetical RDD Ground Level Time-integrated Dose



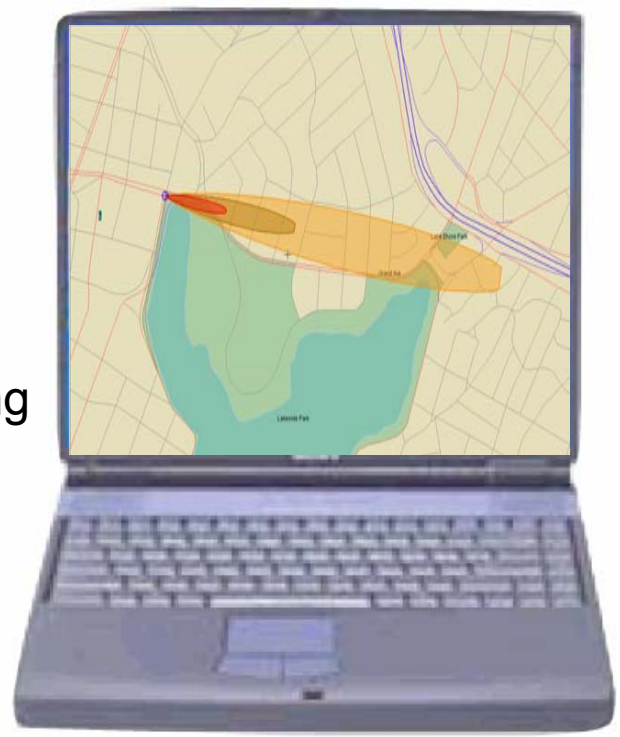
Detonation Point

Northward transport due to surface winds

Fumigation (downward mixing of upper level cloud) after sunrise

Fast-running Local Dispersion Modeling Tools Provide Quick Initial Response and Allow Deployed Use

- Local-scale, deployable models can be used for quick initial estimates of the magnitude of an incident, followed by more-detailed centralized models for longer range predictions
- The *NARAC iClient/Web* software includes simple, fast-running (less than one minute) Gaussian-plume models (*Hotspot*, *EPICode*)
- NARAC is collaborating with several groups on standardization and integration with standalone modeling tools:
  - EPA/NOAA *CAMEO/ALOHA* software (toxic industrial chemical database and plume modeling software)
  - Sandia National Laboratories explosive prompt effects and dispersal modeling tools
  - NRC *RASCAL* nuclear power plant source term model



Standardization of NARAC and EPA/NOAA CAMEO/ALOHA Databases and Products Make National Tools More Complementary

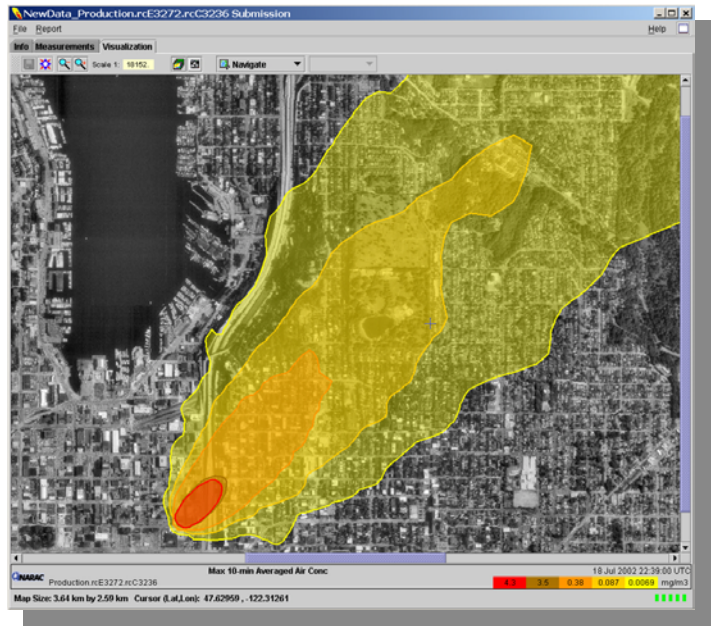
- Completed standardization of hazard levels and color for both ALOHA v5.3 and NARAC plume modeling results

  Red: life threatening effects (AEGL3, ERPG3 or TEEL3)

  Orange: serious long-lasting effects (AEGL2, ERPG2 or TEEL2)

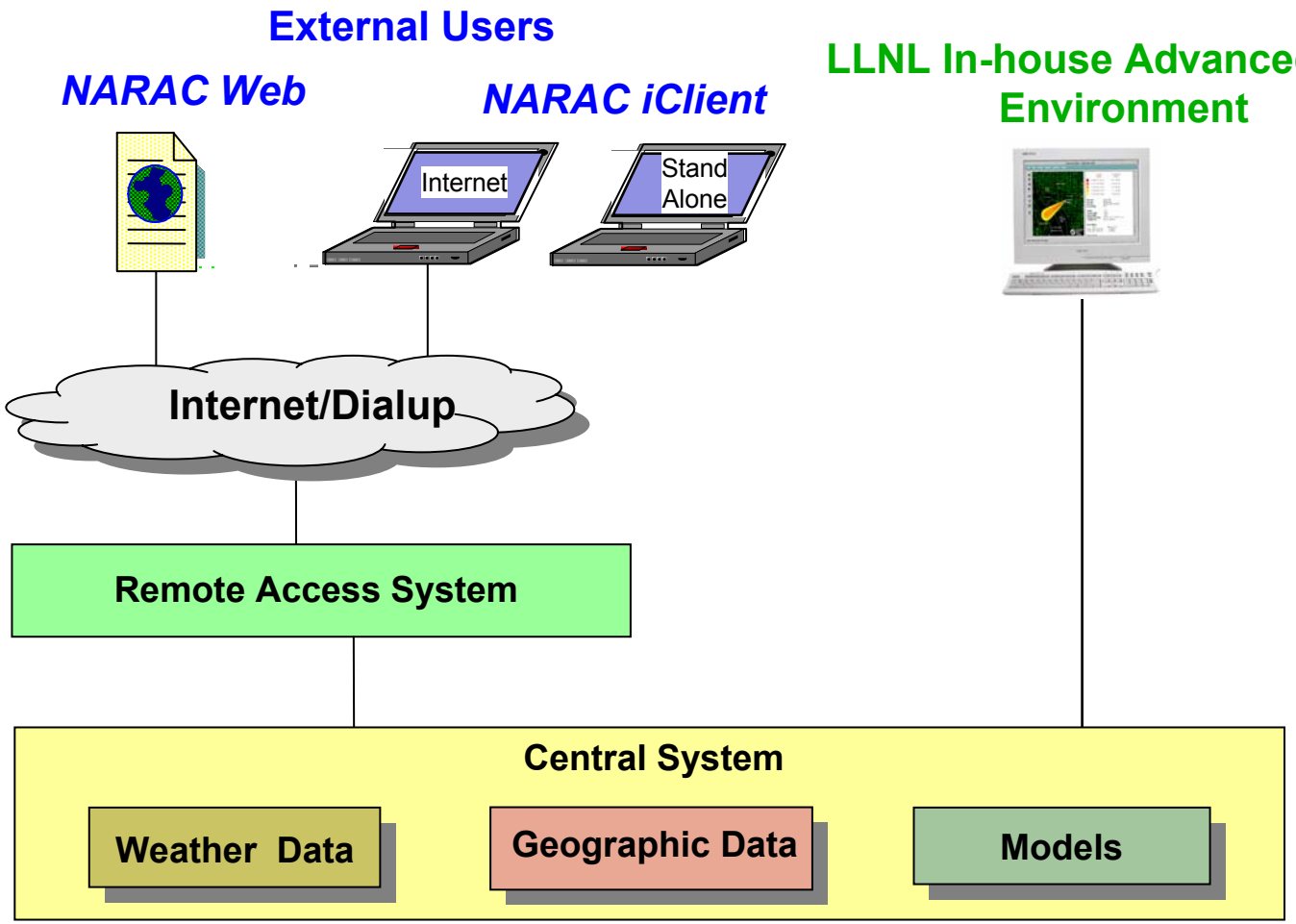
  Yellow: notable discomfort (AEGL1, ERPG1 or TEEL1)

- Chemical properties database standardized between CAMEO/ALOHA and NARAC
- Design of Software interface between CAMEO/ALOHA and NARAC iClient



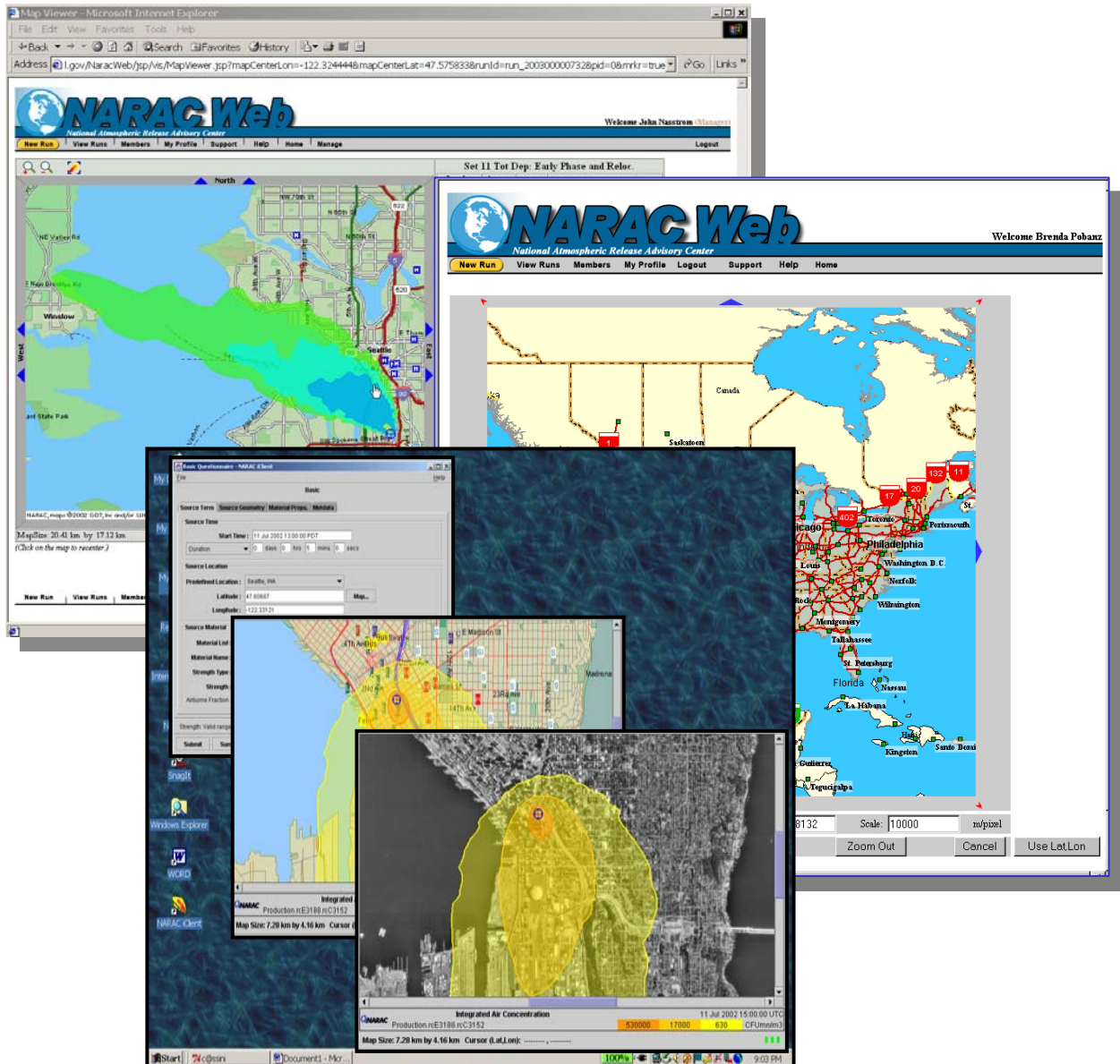
AEGL: EPA Acute Emergency Guideline Level
ERPG: American Industrial Hygiene Association (AIHA) Emergency Response Planning Guideline
TEEL: DOE Subcommittee on Consequence Assessment & Protective Actions (SCAPA) Temporary Emergency Exposure Limits

Component-based LLNL NARAC-IMAAC Computer Systems Support In-house and External Users



Web and *iClient* Software Tools Provide Remote Users with Access to NARAC-IMAAC Predictions

- Automated reach-back to plume modeling with real-time weather data
- Sharing of predictions with other users or groups of users through *IMAAC/NARAC Web*
- Stand-alone capabilities: Simple Models and geographical information displays (*iClient*)



Internet- and Web-based Software Tools Provide Easy Access and Distribution of Predictions

Emergency Operations Center

Information distribution & decision making

Local, Regional, State Responders

Internet, dial-up, satellite or wireless communication

Web-based information Distribution (IMAAC/ NARAC Web)

- **Fast-running local models**
- **Access to advanced models (*iClient*)**

- **Advanced modeling tools**
- **Scientific support and analyses**

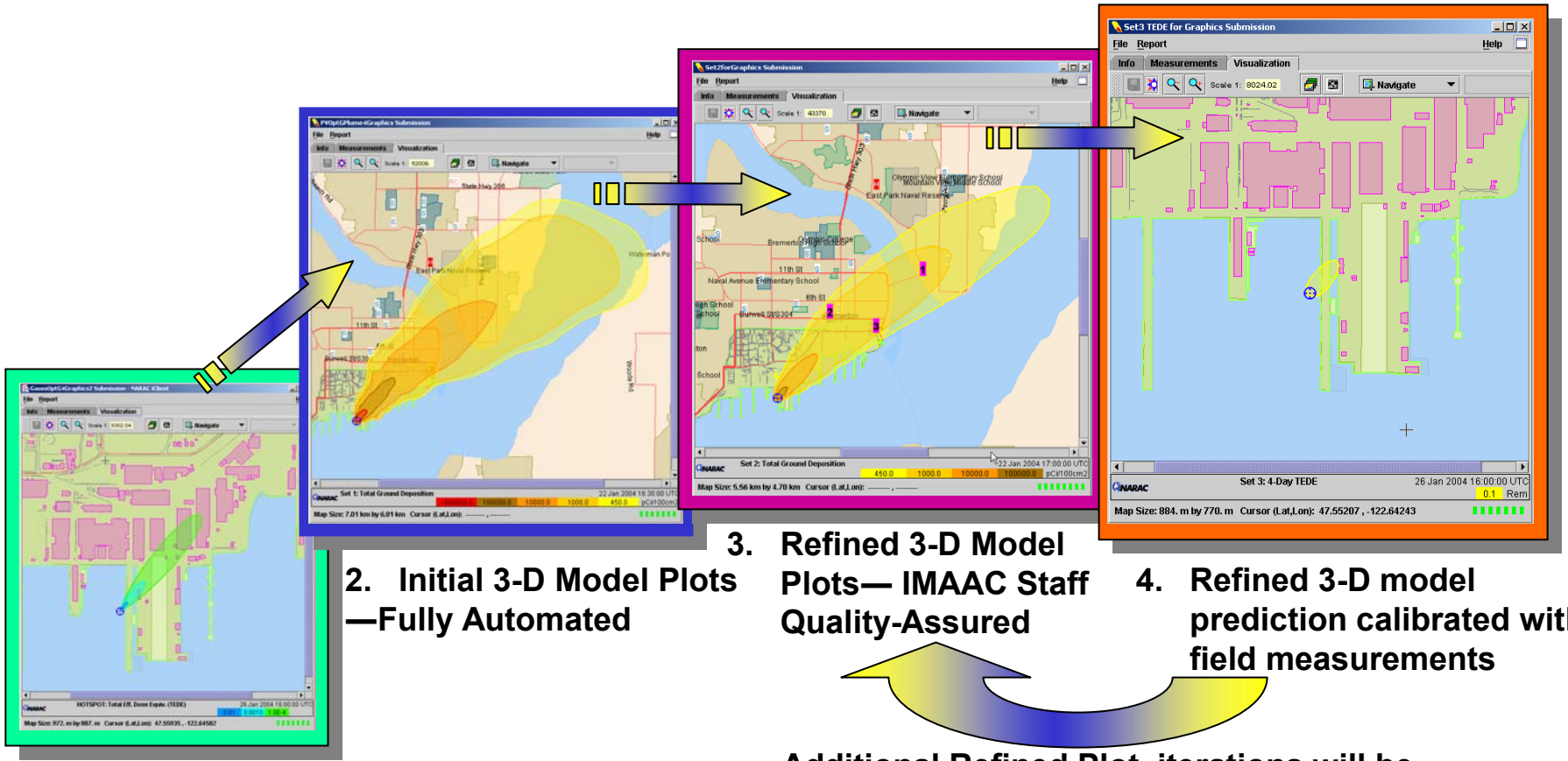
Collaborating City, County, State & Federal Agencies

Incident Support Examples

NARAC/IMAAC Program
Lawrence Livermore National Laboratory

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

NARAC-IMAAC Phased Response Concept of Operations



1. Initial Local Model Run quickly

2. Initial 3-D Model Plots —Fully Automated

3. Refined 3-D Model Plots— IMAAC Staff Quality-Assured

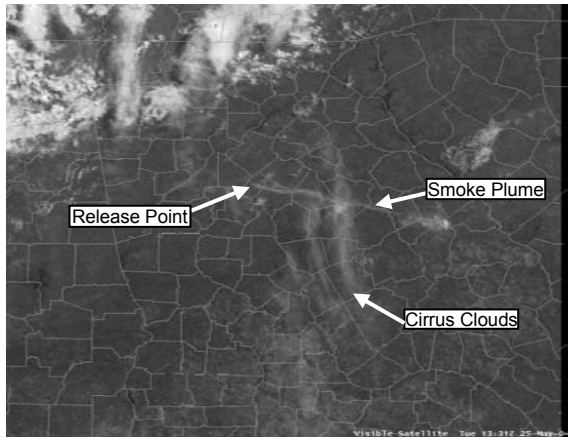
4. Refined 3-D model prediction calibrated with field measurements

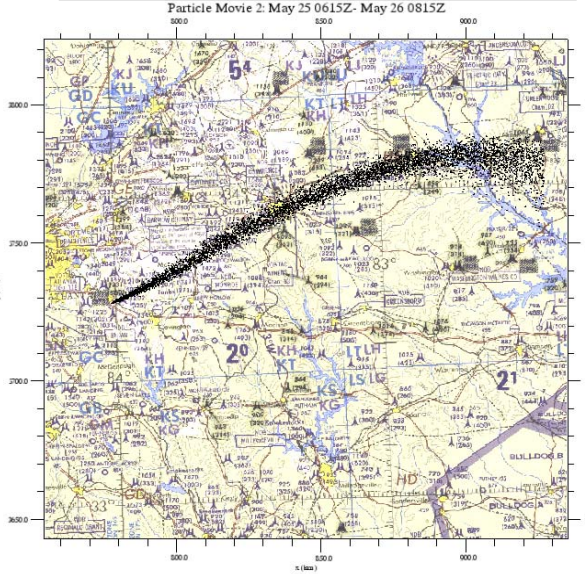
Additional Refined Plot iterations will be made for new measurements sets

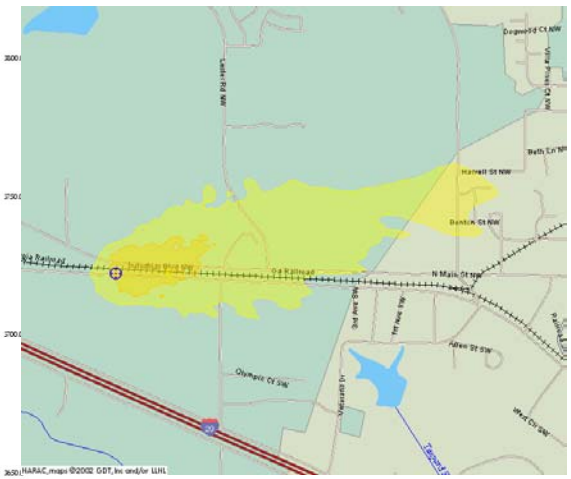
1-2 minutes | 10–15 minutes | 30-60 minutes | Less than 2 hours

IMAAC/NARAC Inter-Agency Response to Conyers, GA Chemical Plant Fire

Particle Movie 2: May 25 0615Z- May 26 0815Z







NARAC

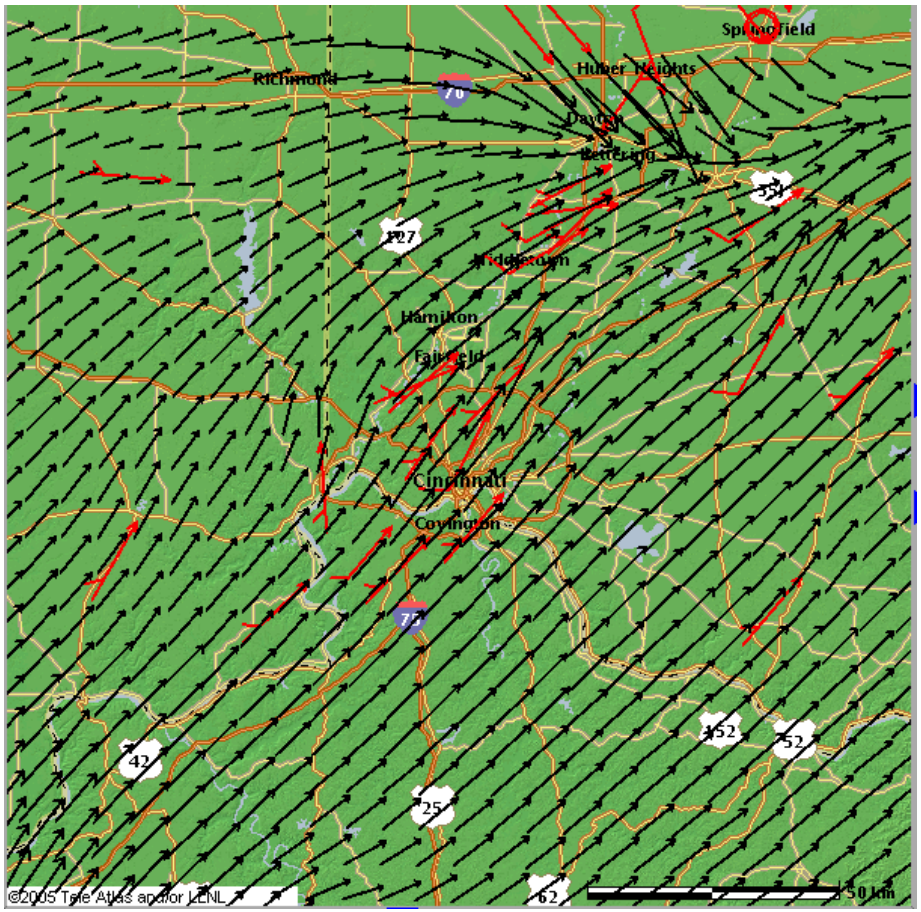
- 250,000 lbs of chlorine compounds burned over a two-day period (May 25-26, 2004)
- Current conditions and forecasts
- Plume predictions refined with EPA field measurements
- IMAAC/NARAC products used by Federal (DHS, DOE, EPA), state of Georgia, and local officials to guide:
  - Location of incident command sites
  - Safe approach routes
  - Sheltering and Evacuation areas
  - Guiding sampling teams

Example of Real-time Support for Massive Cincinnati Fire

- 7:25pm. Massive fire begins at illegal chemical storage facility (50000 drums)
- Cincinnati Fire Department immediately concerned about potential health effects from unknown chemicals in the smoke
- 7:45pm. Ohio LINC Assistance Team (Fire, Health and Environmental Departments) activates and requests LLNL assistance
- 7:54 pm. IMAAC distributes initial predictions via Web
- 8:00pm. Cincinnati uses initial predictions to guide approach routes, air sampling, and shelter-in-place recommendations

Queen City Barrel chemical warehouse fire
August 19, 2004

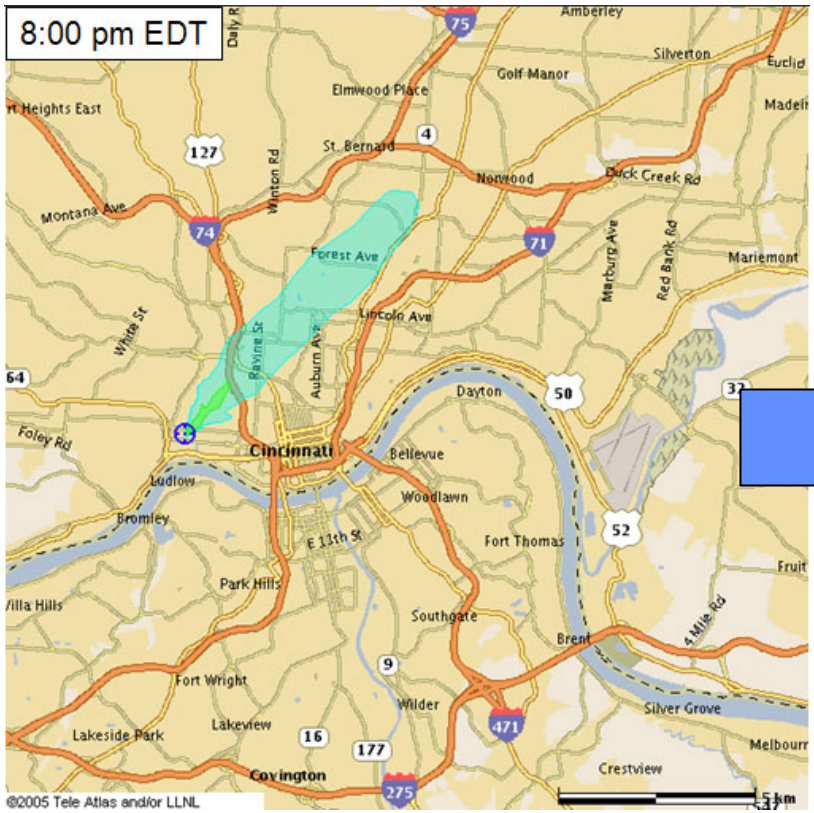
LLNL IMAAC Analyzed and Selected Local and Regional Weather Observations and Forecasts



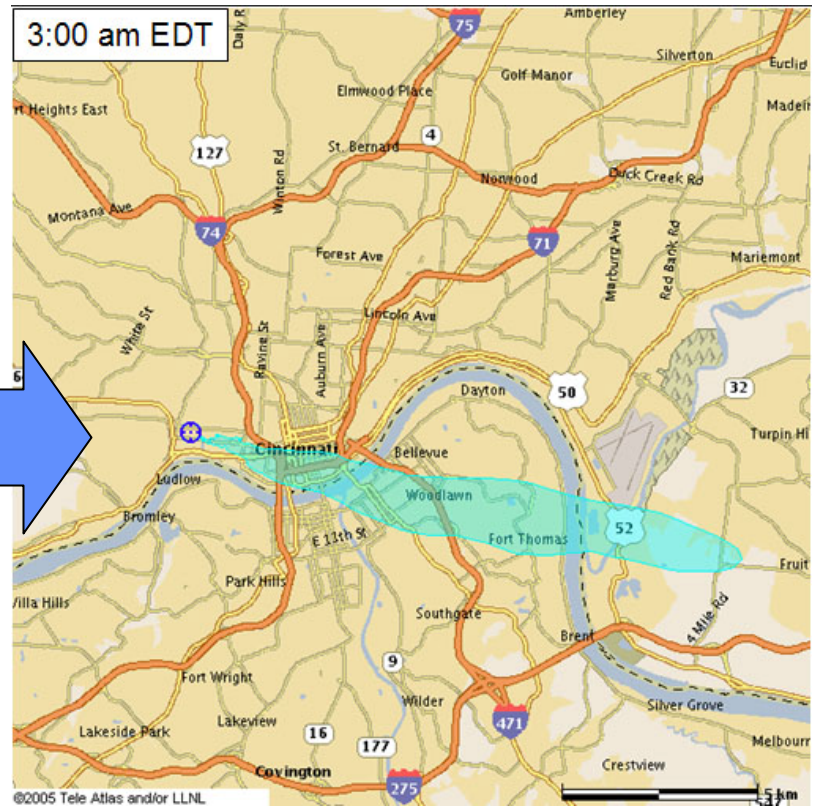
- Analysis of local and regional weather observations
- Selection of National Weather Service Eta model as the best forecast data

Local and regional surface observations (red arrows) and surface wind pattern (black vectors from LLNL ADAPT model) at time near the beginning of the fire

LLNL IMAAC Provided Updated Plume Maps for Forecast Weather Changes



Initially the fire plume headed to the Northeast.



Later in the night (after the weather front passed), the plume headed to the Southeast.

- National Weather Service Eta model was selected to provide forecast weather conditions
- Changing conditions communicated to Cincinnati, Ohio, and EPA incident command and responders

NARAC-IMAAC Research and Development

NARAC/IMAAC Program
Lawrence Livermore National Laboratory

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Our Current Research is Focused on Complex Environments, Sources, and Using Sensor Data

- Urban dispersion
  - Faster high-resolution simulation
  - Empirical approaches to urban simulation
  - Indoor/outdoor coupling and effects inside buildings
- Event reconstruction: rapid inclusion of sensor data, and probabilistic predictions
- Improved fallout models
- Radiological, chemical, and biological source models
- Improved health effect and consequence models
- Precipitation scavenging
- High altitude dispersion (missile intercept)
- Chemical reaction in dispersion codes

Our Research & Development Relies on Extensive Scientific Collaborations

LLNL Computations, Engineering, Physics, Defense and Nuclear Technologies staff

UC Berkeley: urban atmospheric turbulence, event reconstruction

NCAR: operational forecasting, incorporating nowcasting and variational data assimilation

NOAA/ Field Research Division: field experiments

NOAA Aeronomy Lab/CIRES: boundary-layer height prediction and quantification

Univ. Colorado, CIRES: turbulence/diffusion model parameterizations

EPA/NOAA Hazardous Material Response and Assessment Division: Standardization and integration of CAMEO/ALOHA models

NRC: Interface nuclear power plant source characteristics (RASCAL code)

ESRI, Inc. and DOE Remote Sensing Laboratory RSL: Interfaces between modeling systems and GIS software

DTRA: Urban field experiments, model verification and validation, fallout modeling

LBNL: indoor exposures

UK Defence Science and Technology Laboratory (Dstl): Empirical urban model

NRL: Mesoscale modeling and COAMPS

PNNL: Urban field studies

LANL: Urban Dispersion Program

LANL/ORNL: Day-night population density

ORNL: Acute and chronic radioactive dose models

SNL: Acute dose, casualty/fatality estimates and prompt effects from explosions

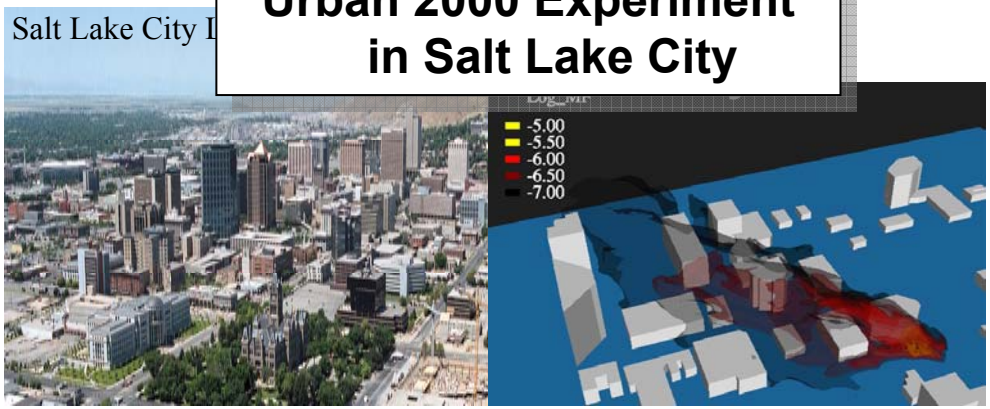
SNL: CBRNE source characteristics

SNL/RSL: Integration of field measurement database into modeling tools

U.S. Army ECBC: New dose-response relationships and toxic load models for chem./bio. agents

LLNL is Collaborating with Multiple Agencies on Urban Experiments to Test and Develop Urban Flow and Dispersion Models

Urban 2000 Experiment in Salt Lake City

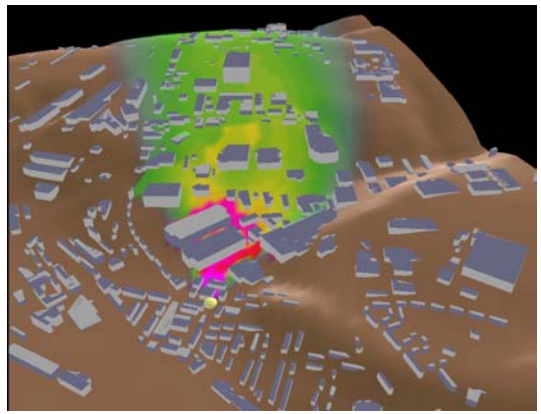


Joint-Urban 2003 Experiment in Oklahoma City

NYC Urban Dispersion Program

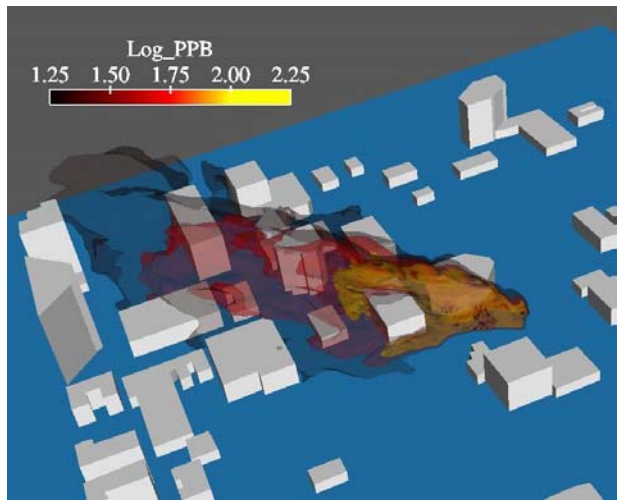
Ongoing Development: Building-scale Flow and Dispersion Models

- Fast-running empirical UDM urban model (developed by UK DSTL)



UDM Model

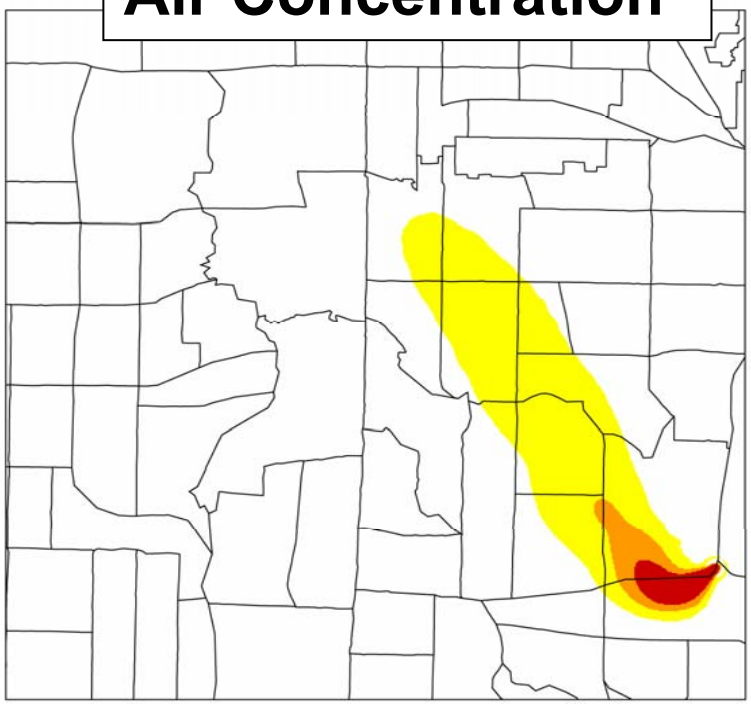
- High-resolution building-scale computational fluid dynamics model (FEM)



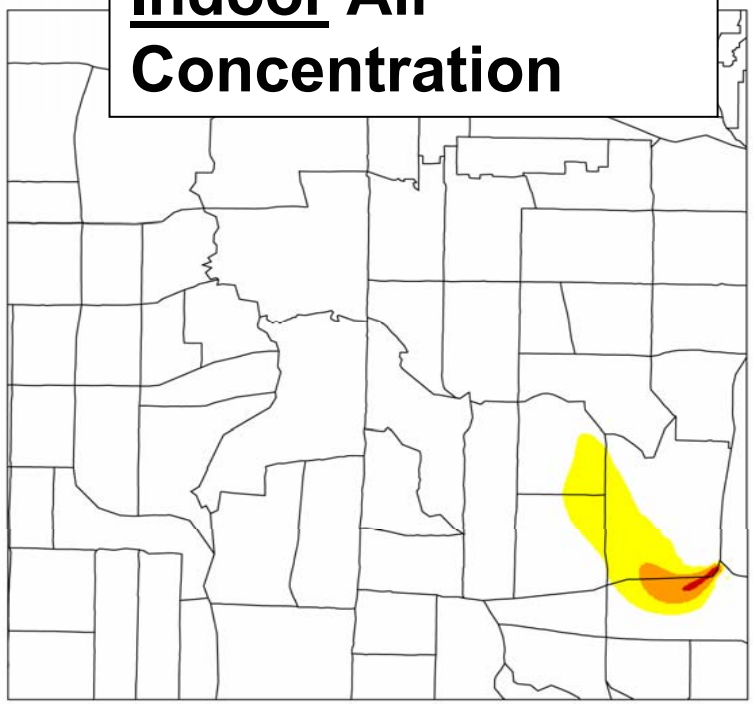
FEM Model

LLNL is Integrating LBNL Research on Outdoor-Indoor Infiltration Models

Outdoor Plume Air Concentration

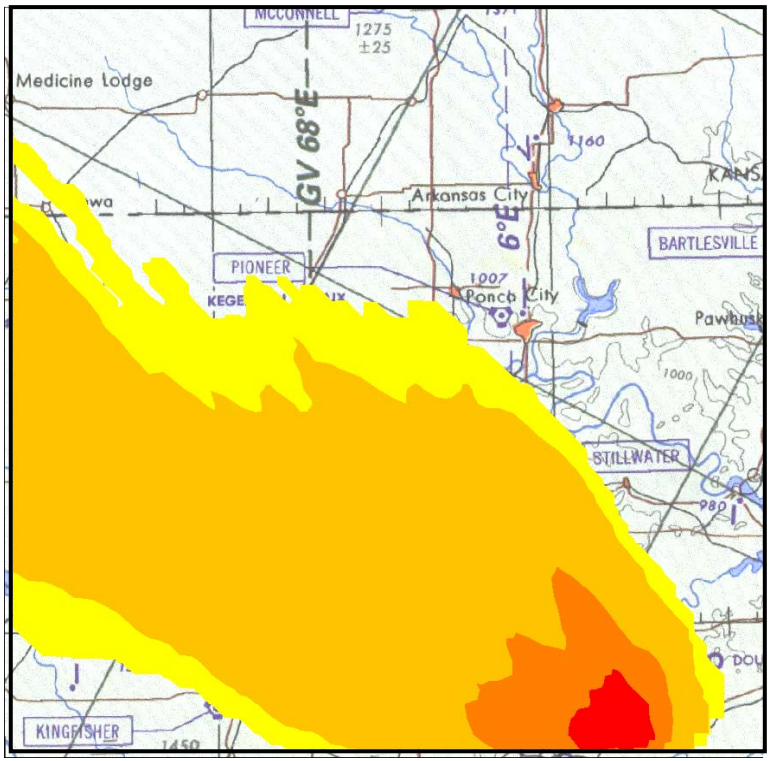


Corresponding Indoor Air Concentration

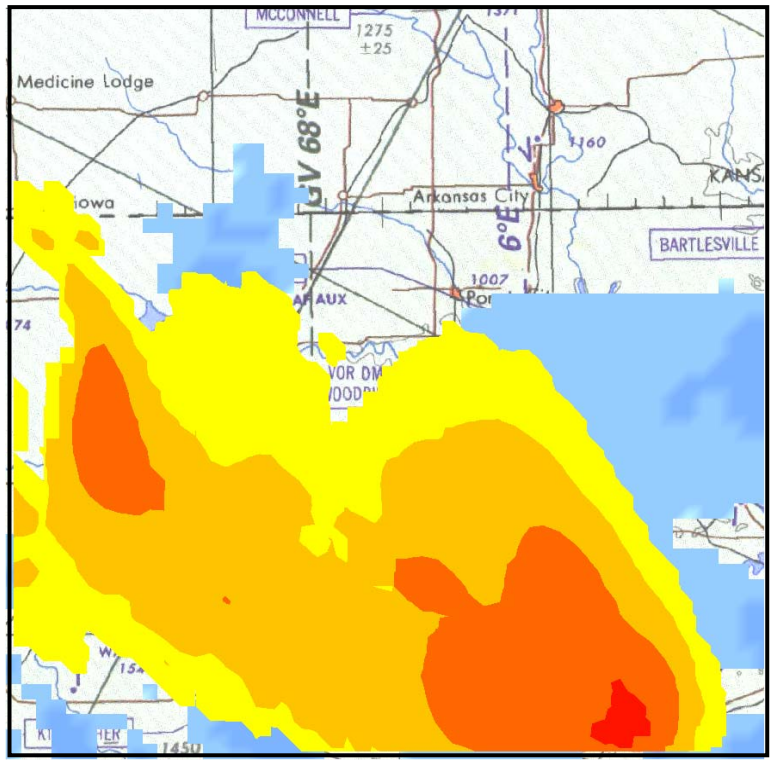


Building leakiness data from several states is used with Census data on residences to infer statistical relationships and derive a U.S.-wide geospatial database

High-resolution Weather Radar data and NARAC/LODI Precipitation Scavenging Model Will Be Able to Simulate Wet Deposition Hotspots



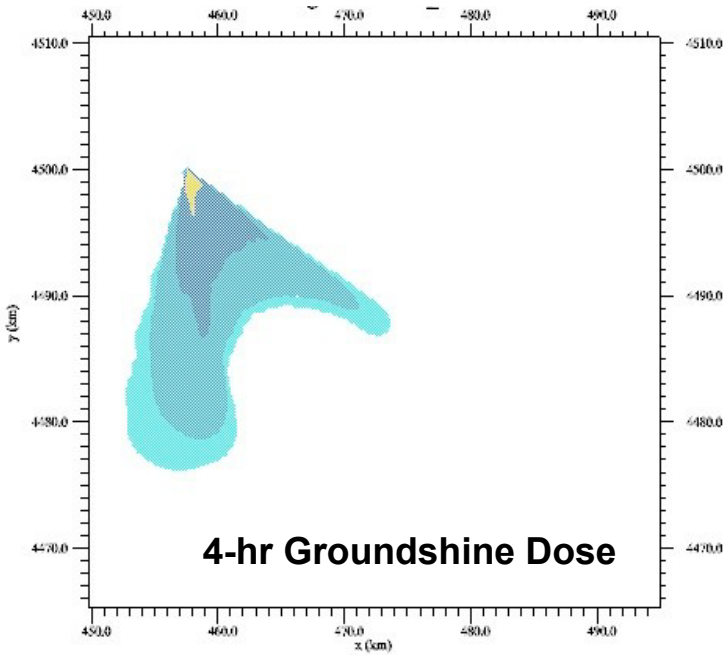
Wet deposition pattern from a continuous source using a uniform constant rain rate (30mm/hr)



Wet deposition pattern using high-resolution weather radar (NEXRAD) precipitation data: Precipitation (blue) creates wet deposition hot spots (yellow-red contours) during a convective storm

Advanced Nuclear Fallout Model Being Developed

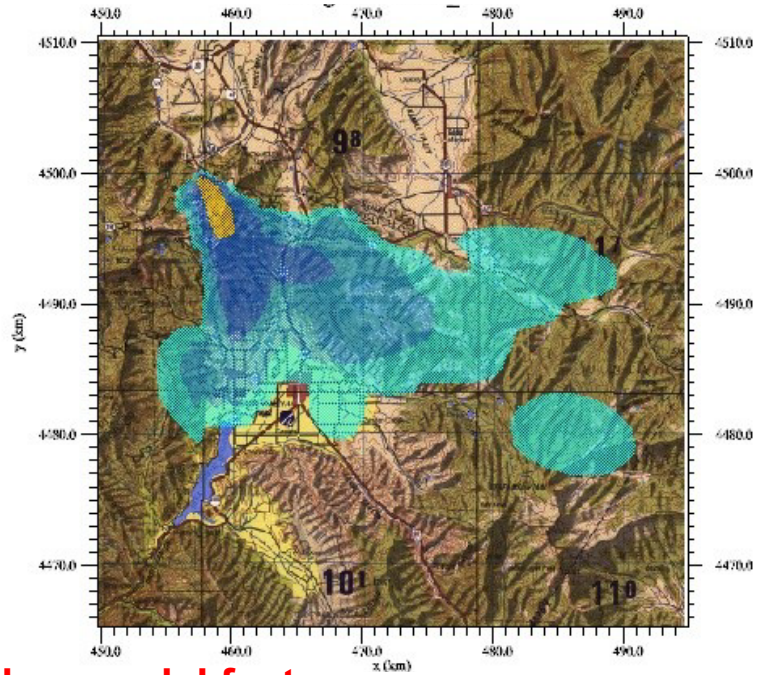
Existing Operational Model (KDFOC)



Existing model features:

- 1-D (vertical) wind variation
- Large fallout particles
- Gross activity
- Groundshine
- Buried, surface or air burst

New Model (LODI-FOC)

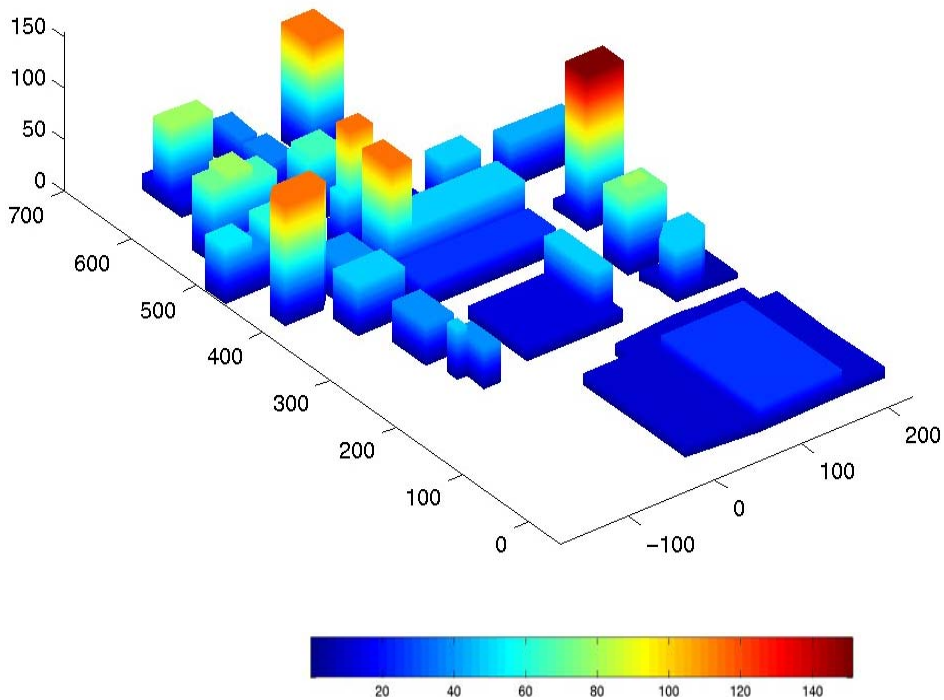


New model features:

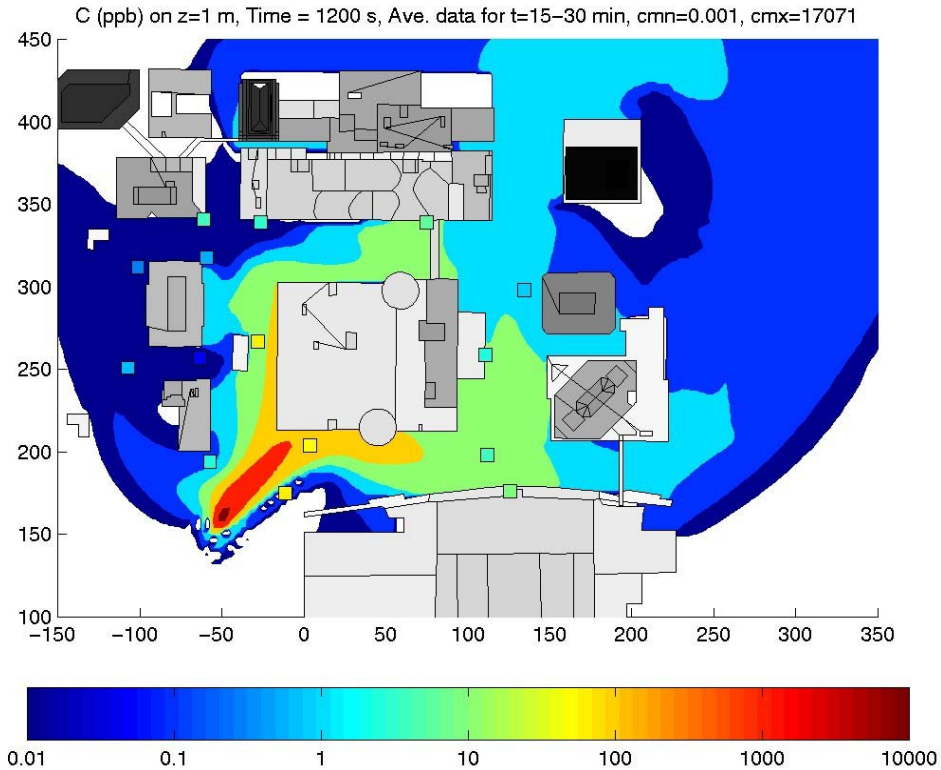
- 4-D wind variation & terrain effects
- Large and respirable particles
- Gross activity & specific nuclides
- Groundshine, cloudshine & inhalation doses
- Rainout
- Long-range transport
- Buried, surface or air burst; Multi-bursts

Joint Urban 2003 (JU2003) Oklahoma City Field Study Data is Used to Evaluate Urban and Event Reconstruction Models

Computational Fluid Dynamics (CFD) Model Explicitly resolves buildings in the source area



CFD Models Can Accurately Simulate Building-Scale Flow and Dispersion (JU2003)



Color contours – CFD model predictions

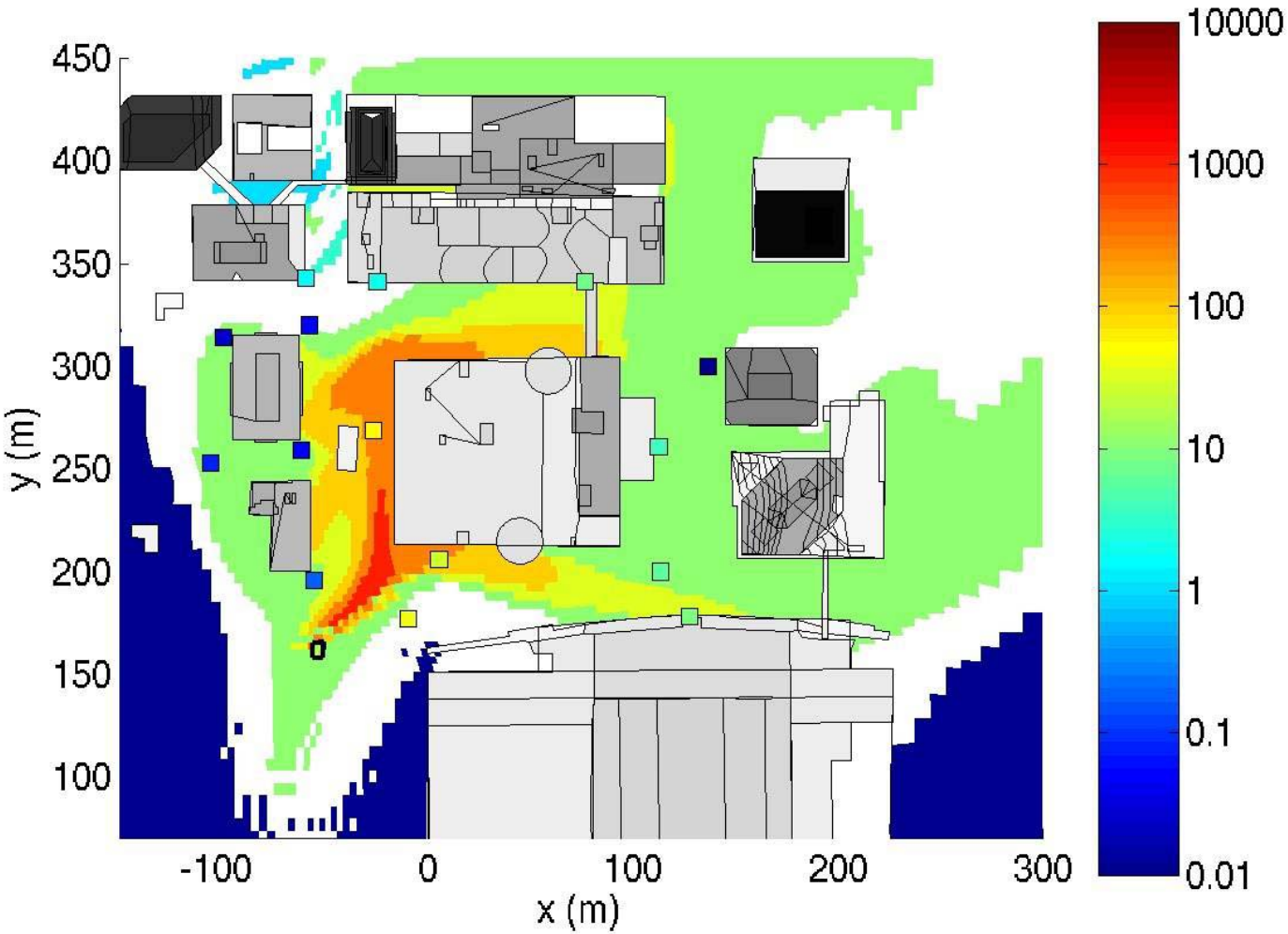
Small squares – measurement data

LLNL is Developing a Rigorous Method for Inverse Modeling and Event Reconstruction

- Goal: Automate the utilization of sensor field measurements to estimate source terms and optimize predictions

- Approach:
  - Couple sensor data and simulation via Bayesian inference, stochastic sampling, and optimization methods
  - Backwards analyses to determine probabilistic distribution of unknown source characteristics
  - Optimal and probabilistic forward plume model predictions

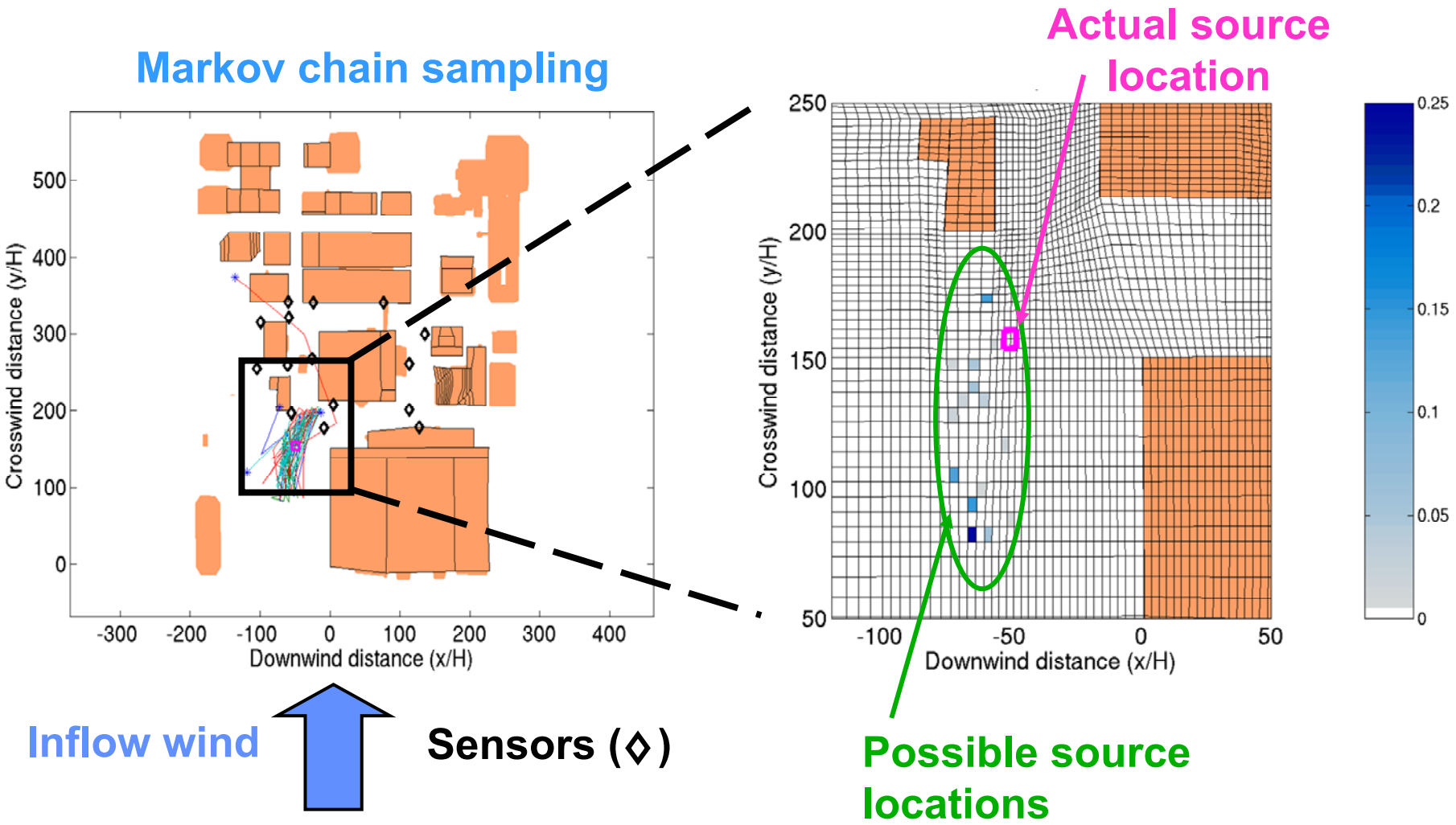
Event reconstruction composite plume provides uncertainty estimate



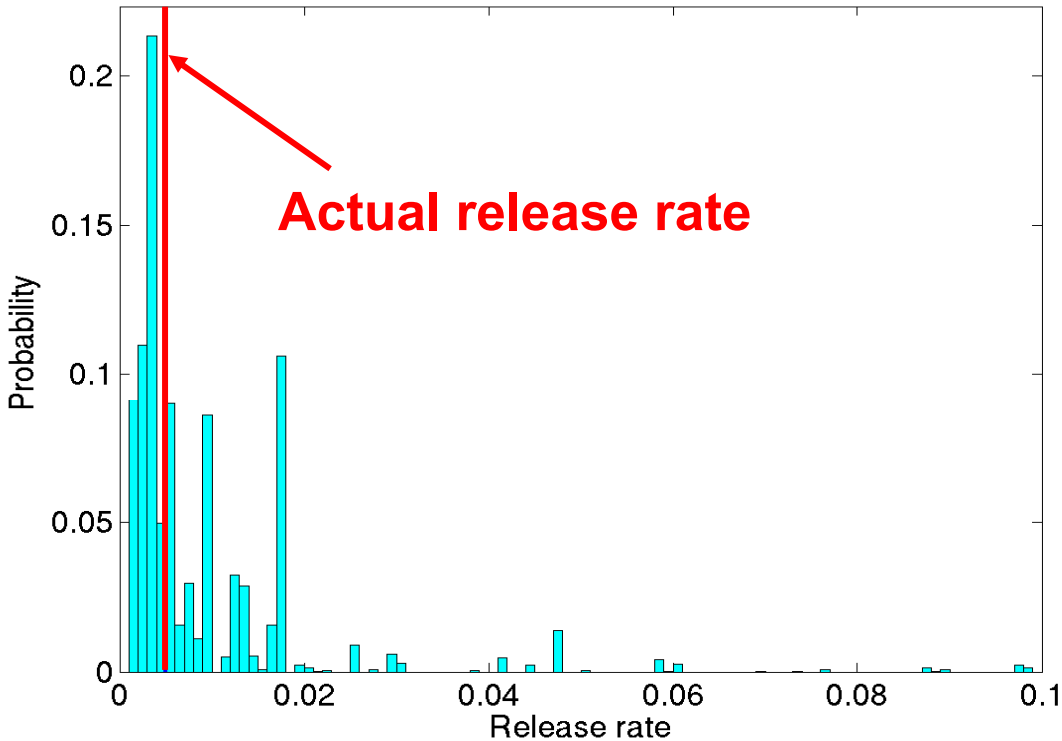
90% confidence level

Not part of original slide set

Possible release locations are identified to within a ~25m x 150m area including the actual source



Histogram shows simultaneous determination of release rate to within 10% of actual value



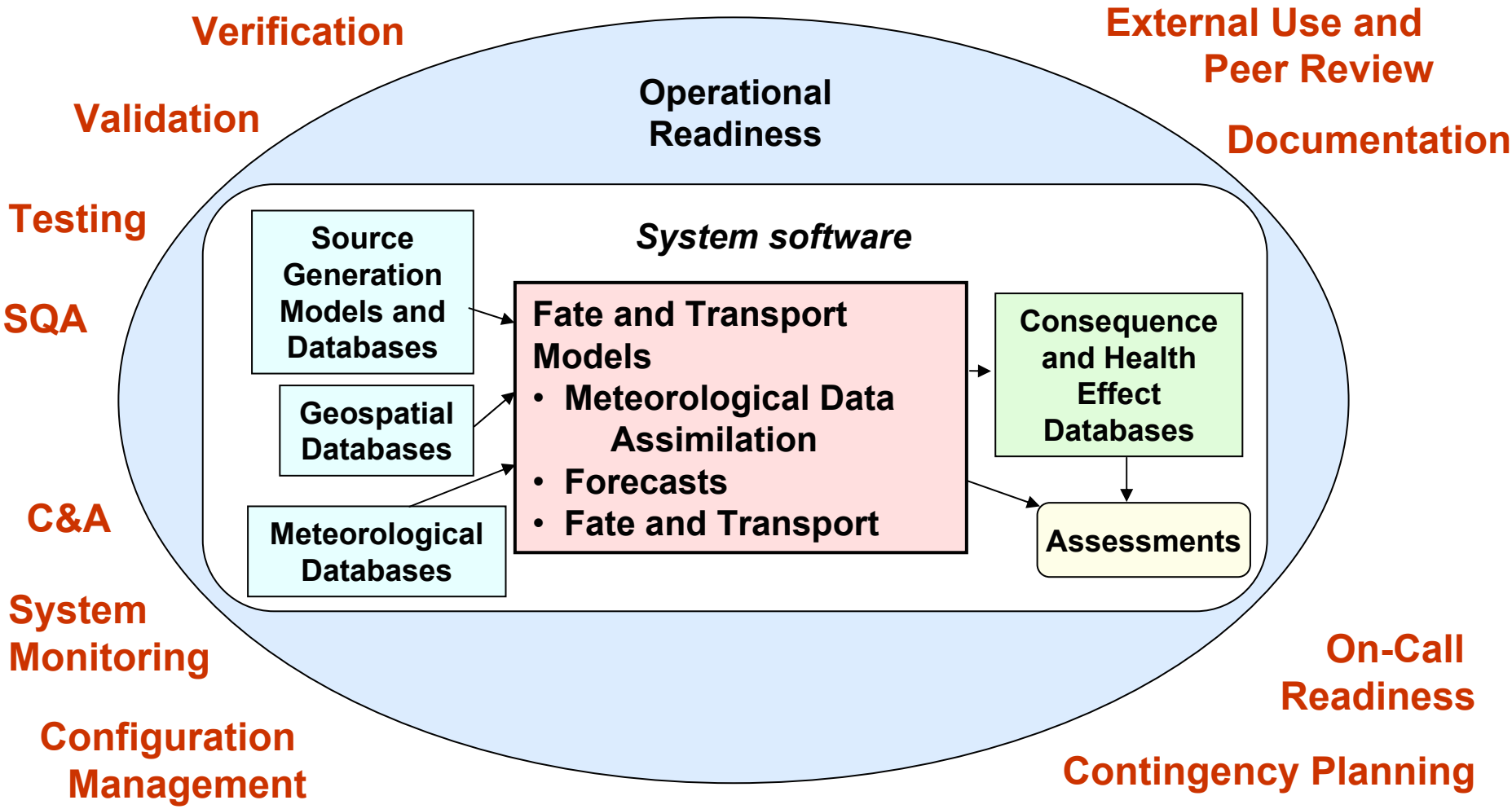
Computational approach uses Green's function methodology
- 2560 pre-computed unit source simulations
- Total CPU = 13,056hrs (12+ hrs on 1024 2.4 GHz Xeon processors)
- Event reconstruction requires ~2 minutes (20000 Markov iterations)

NARAC-IMAAC Model Verification and Validation

NARAC/IMAAC Program
Lawrence Livermore National Laboratory

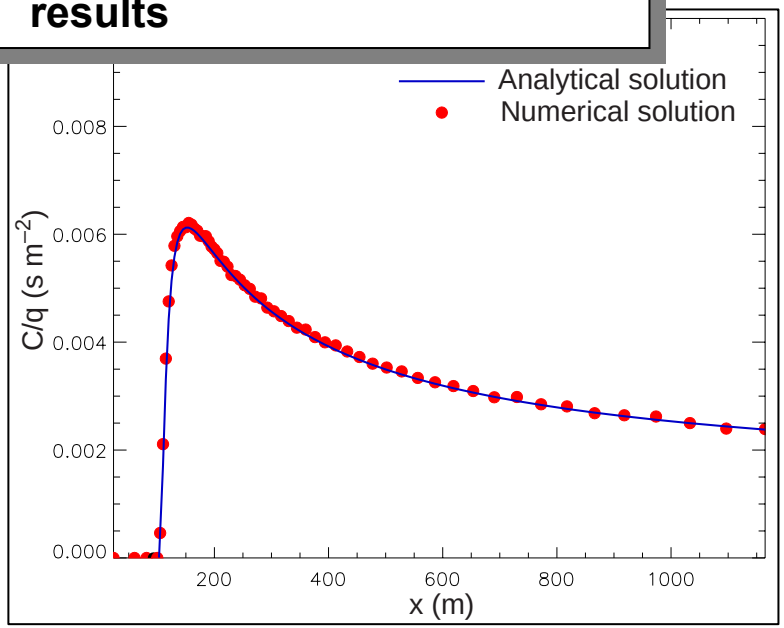
This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

A Comprehensive Approach Ensures Quality, Reliability, and Accuracy



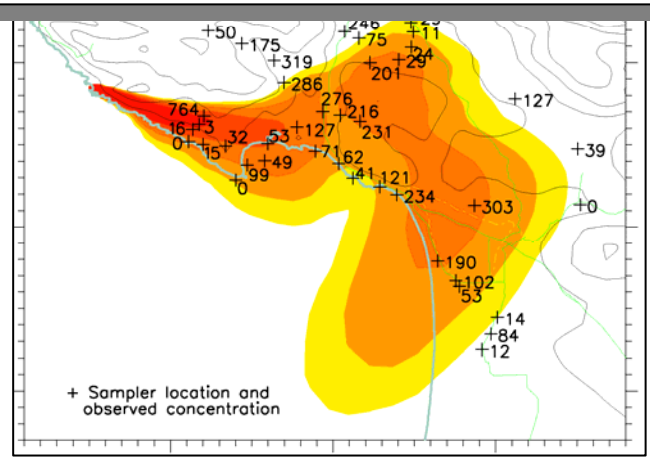
NARAC Models are Extensively Tested and Evaluated

- **Analytic solutions** test models versus known, exact results



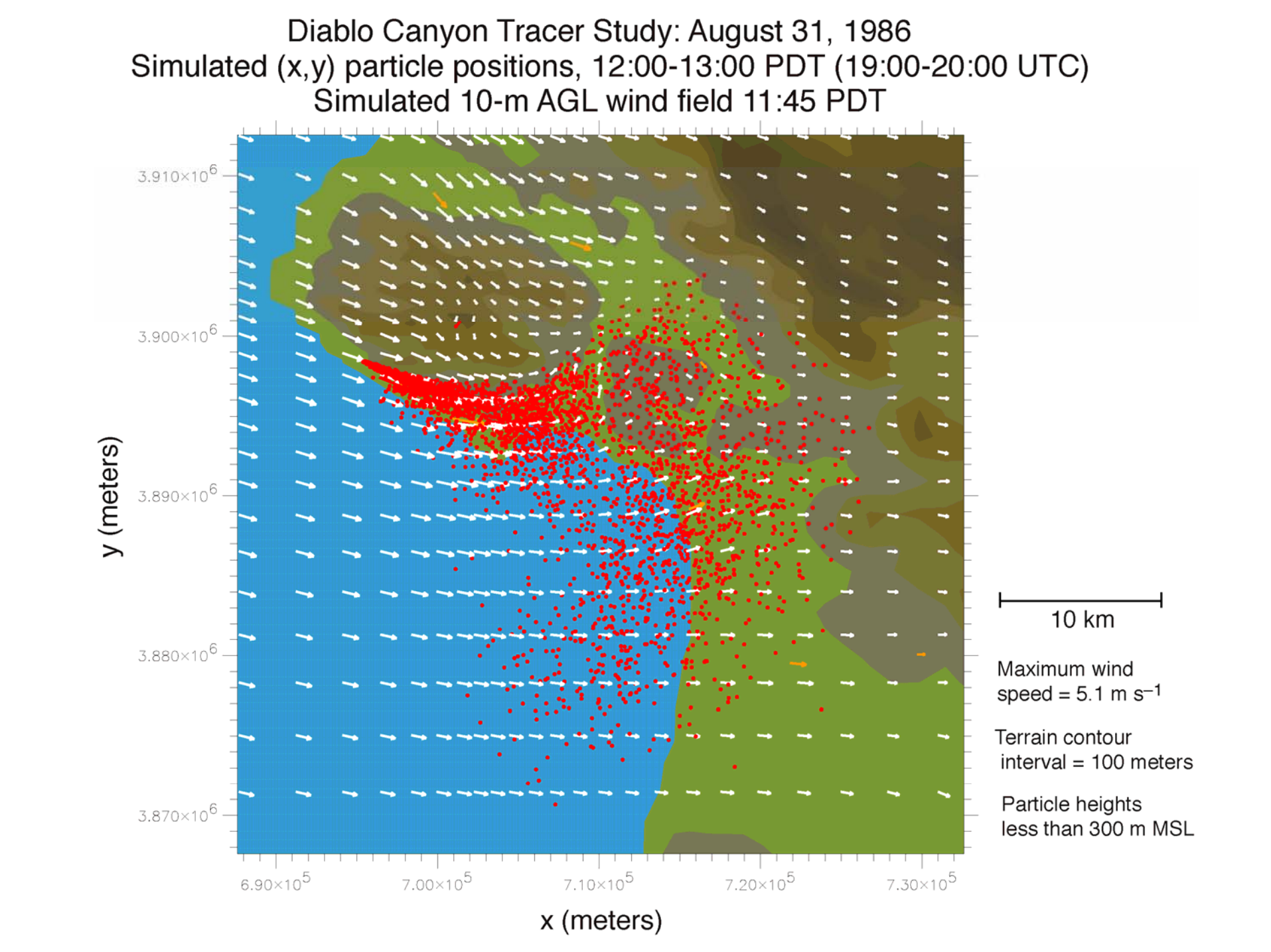
- **Field experiments** test models in real-world cases

Examples: Roller Coaster, Project Prairie Grass, Savannah River Musicale Atmospheric Tracer Studies, Diablo Canyon Tracer Study, ETEX, URBAN

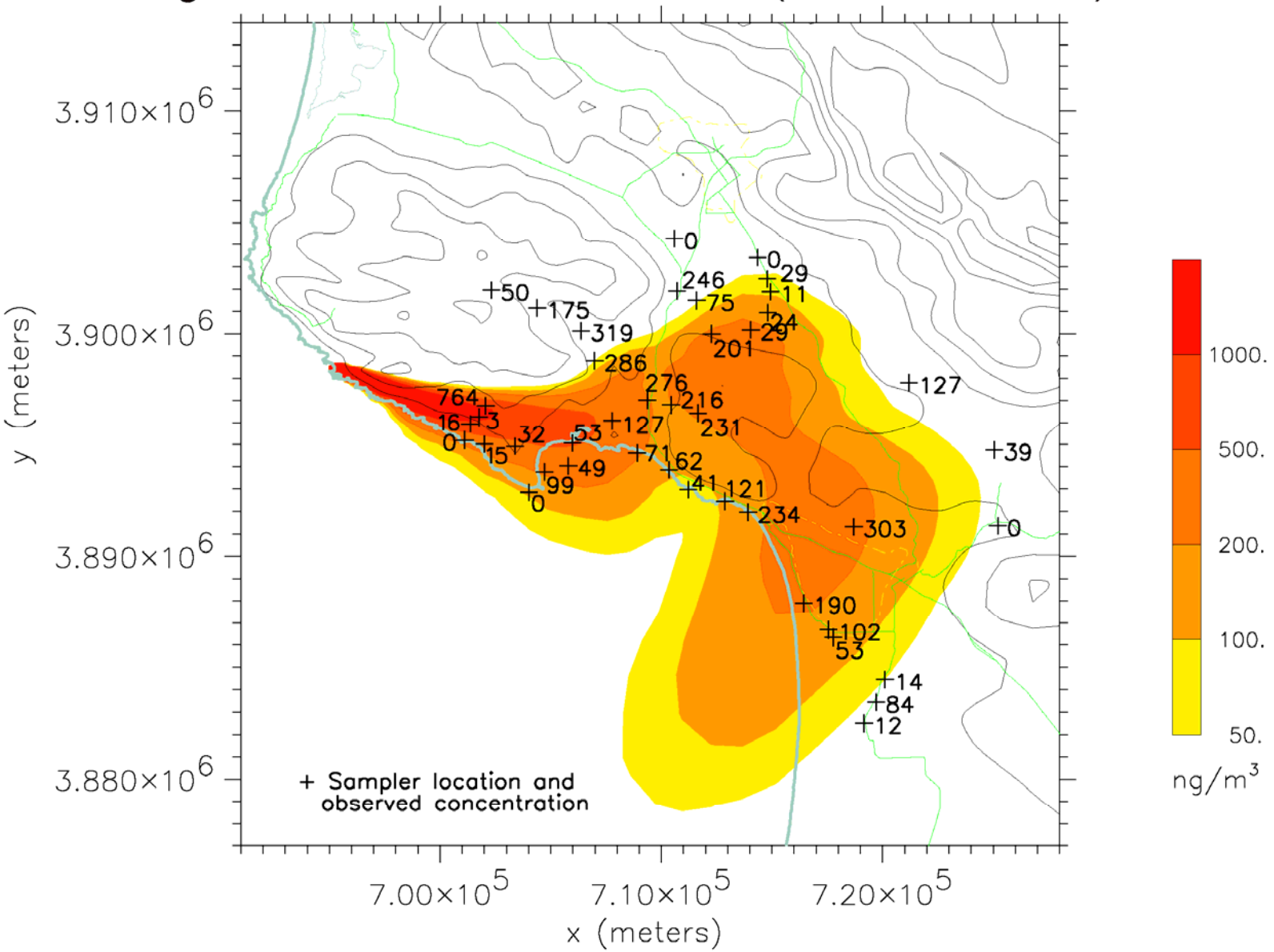


- **Operational testing** evaluates the usability, efficiency, consistency and robustness of models for operational conditions

Examples: Chernobyl, Kuwait oil fires, tire fires, industrial accidents, Algeciras Spain Cesium release, Tokaimura criticality accident, Cerro Grande (Los Alamos) fire


Diablo Canyon Tracer Study: August 31, 1986
Simulated (x,y) particle positions, 12:00-13:00 PDT (19:00-20:00 UTC)
Simulated 10-m AGL wind field 11:45 PDT
y (meters)
3.910×10^6
3.900×10^6
3.890×10^6
3.880×10^6
3.870×10^6
6.90×10^5
7.00×10^5
7.10×10^5
7.20×10^5
7.30×10^5
x (meters)
10 km
Maximum wind speed = 5.1 m s−1
Terrain contour interval = 100 meters
Particle heights less than 300 m MSL

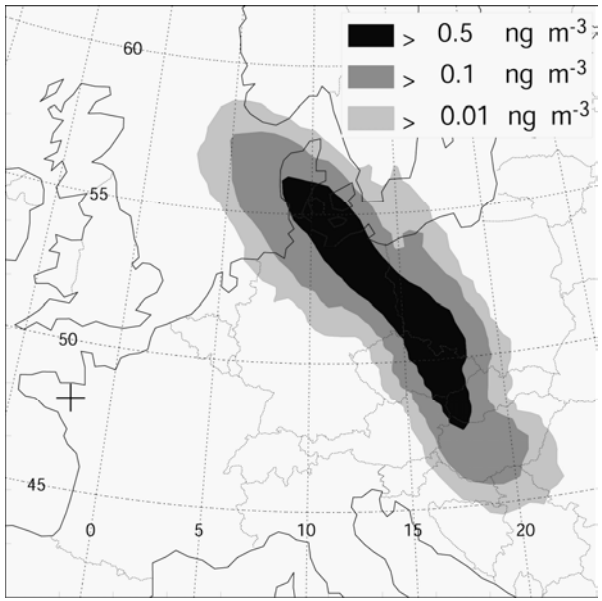
Diablo Canyon Tracer Study:
Simulated and Observed SF_6 1-hr Average Surface Air Concentration
August 31, 1986 12:00-13:00 PDT (19:00-20:00 UTC)



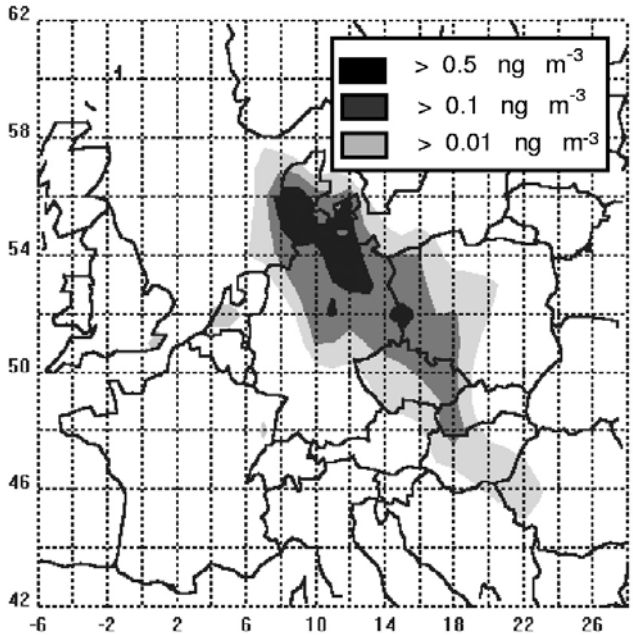
Terrain contour interval = 100 meters

European Tracer Experiment (ETEX) Model Evaluation

NARAC Simulated

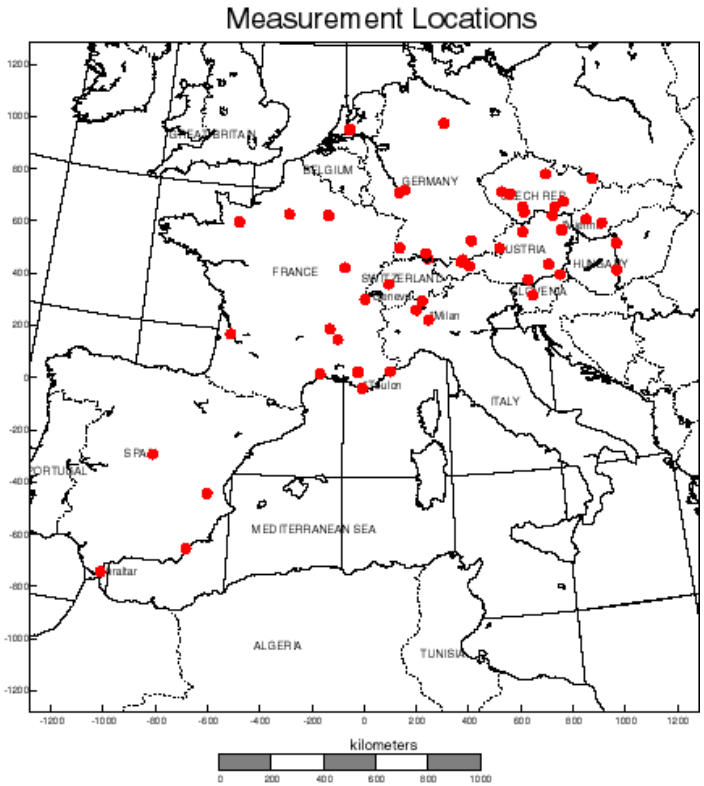


Observed

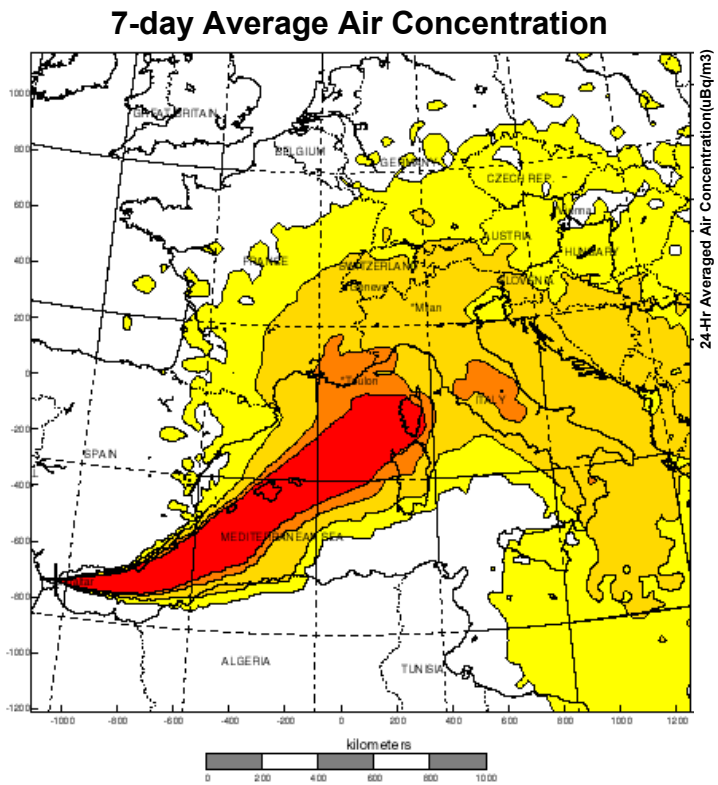


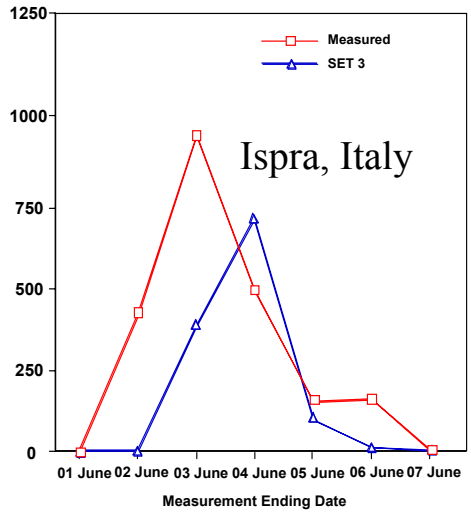
3-hr-average air concentration of perfluorocarbon tracer gas after 48 hours during the first ETEX experiment

Real World Events Further Validate our Capabilities



European Sampler Network Detected Low Levels of Radioactivity May-June, 1998





Time series of 24-hr Average Air Concentration Measured (red) and Model Predicted (blue)

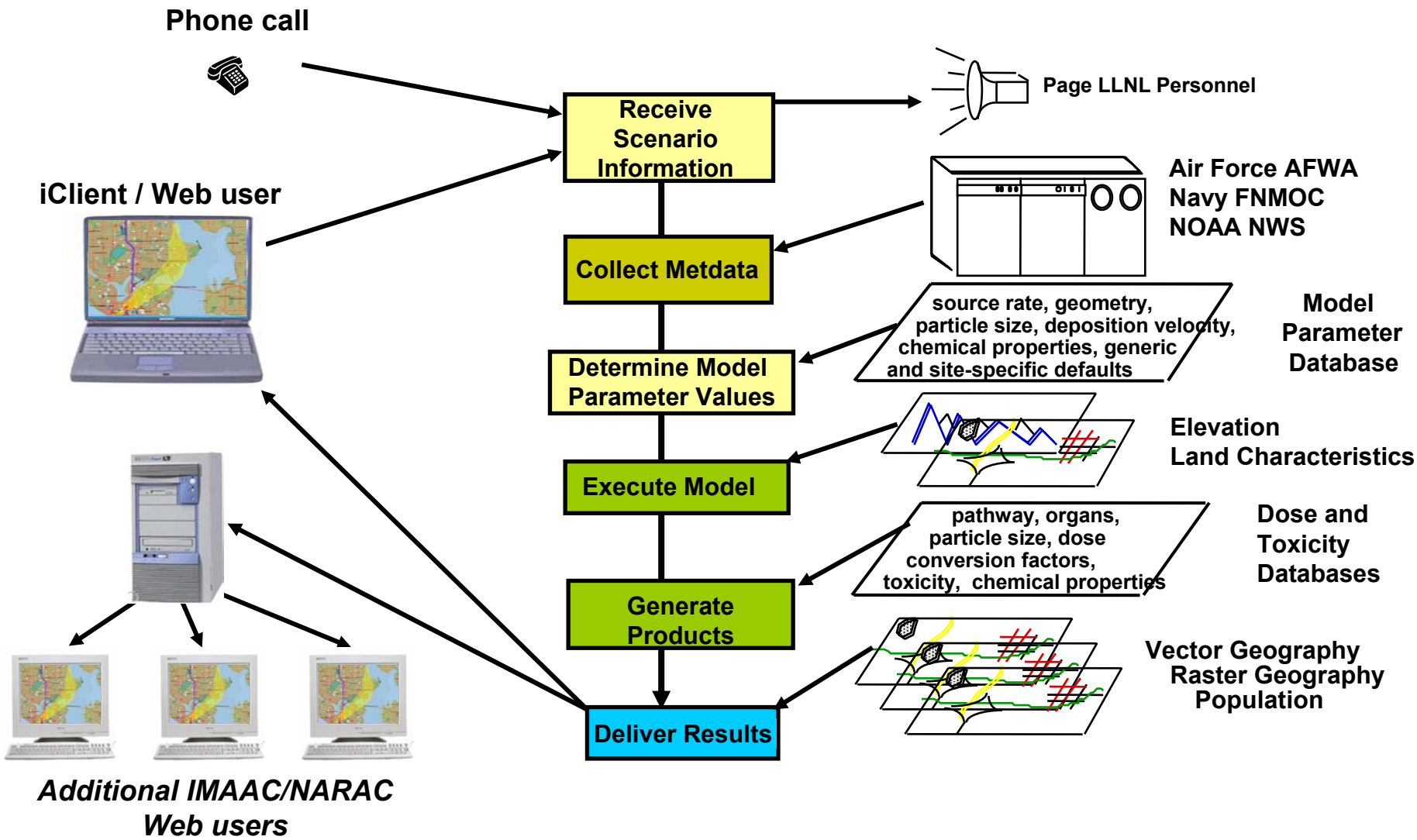
Algeciras, Spain Cesium release
Reference: Vogt et al. (1998)

NARAC-IMAAC Systems and Models

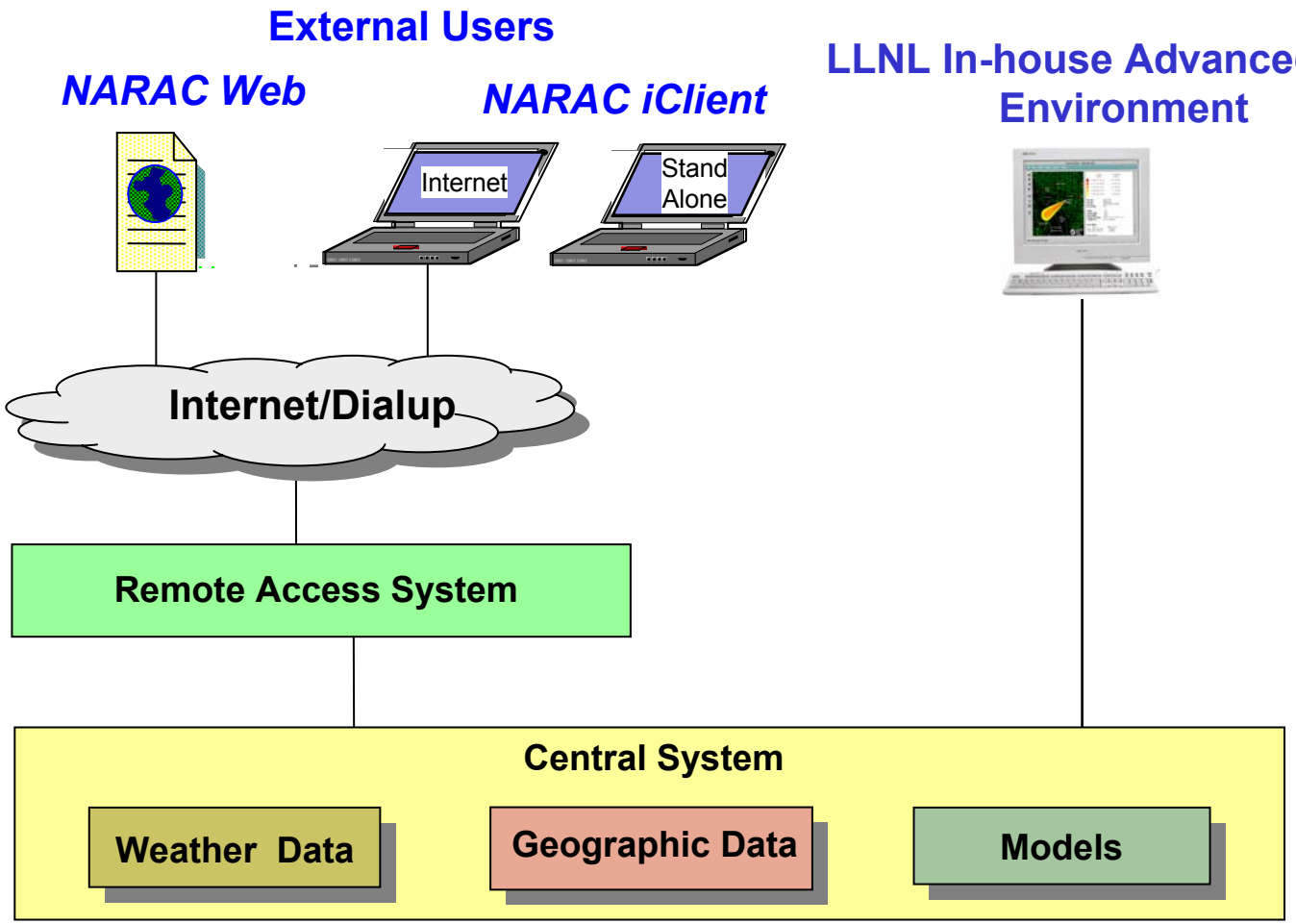
NARAC/IMAAC Program
Lawrence Livermore National Laboratory

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

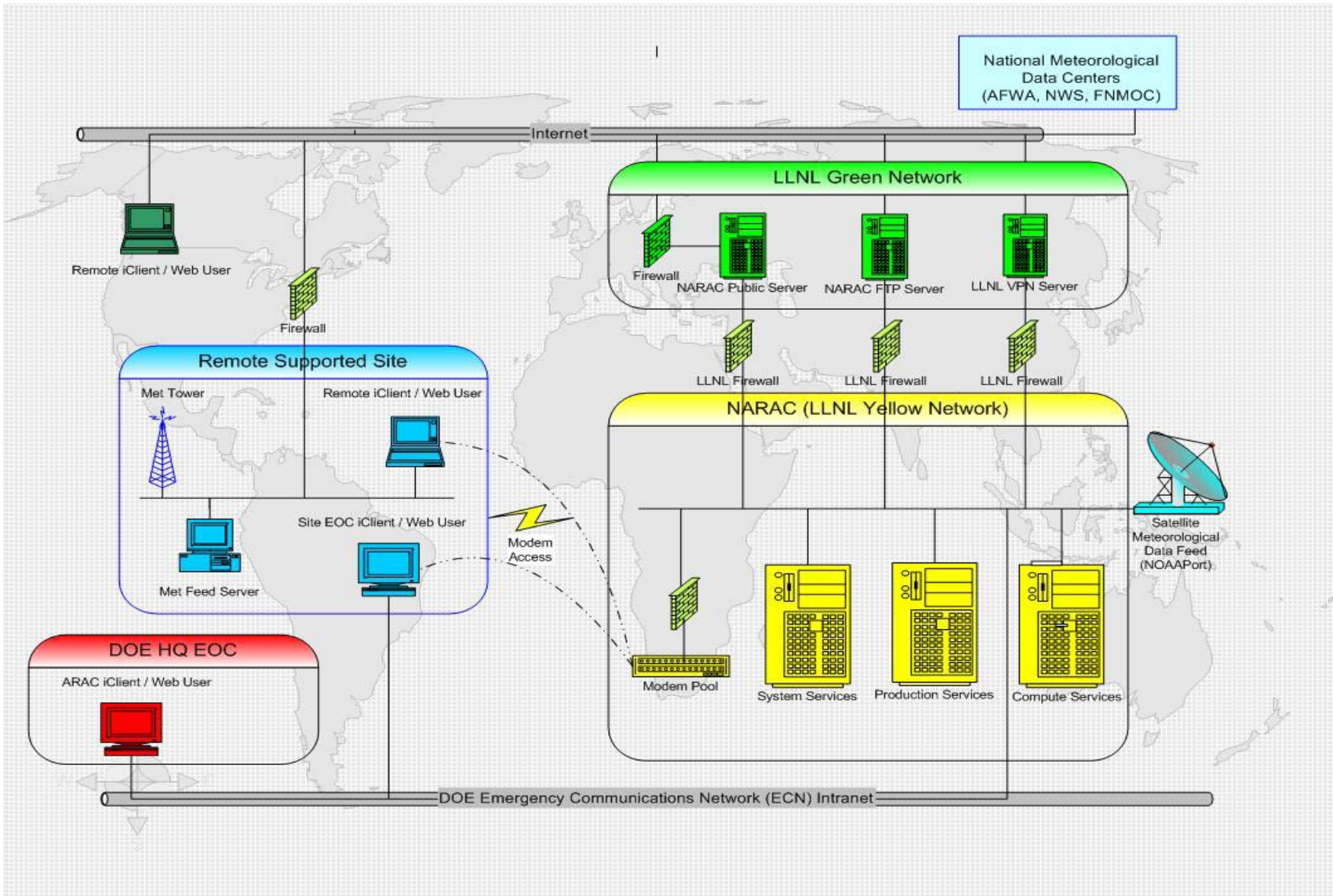
NARAC-IMAAC Processing Steps Are Fully Automated



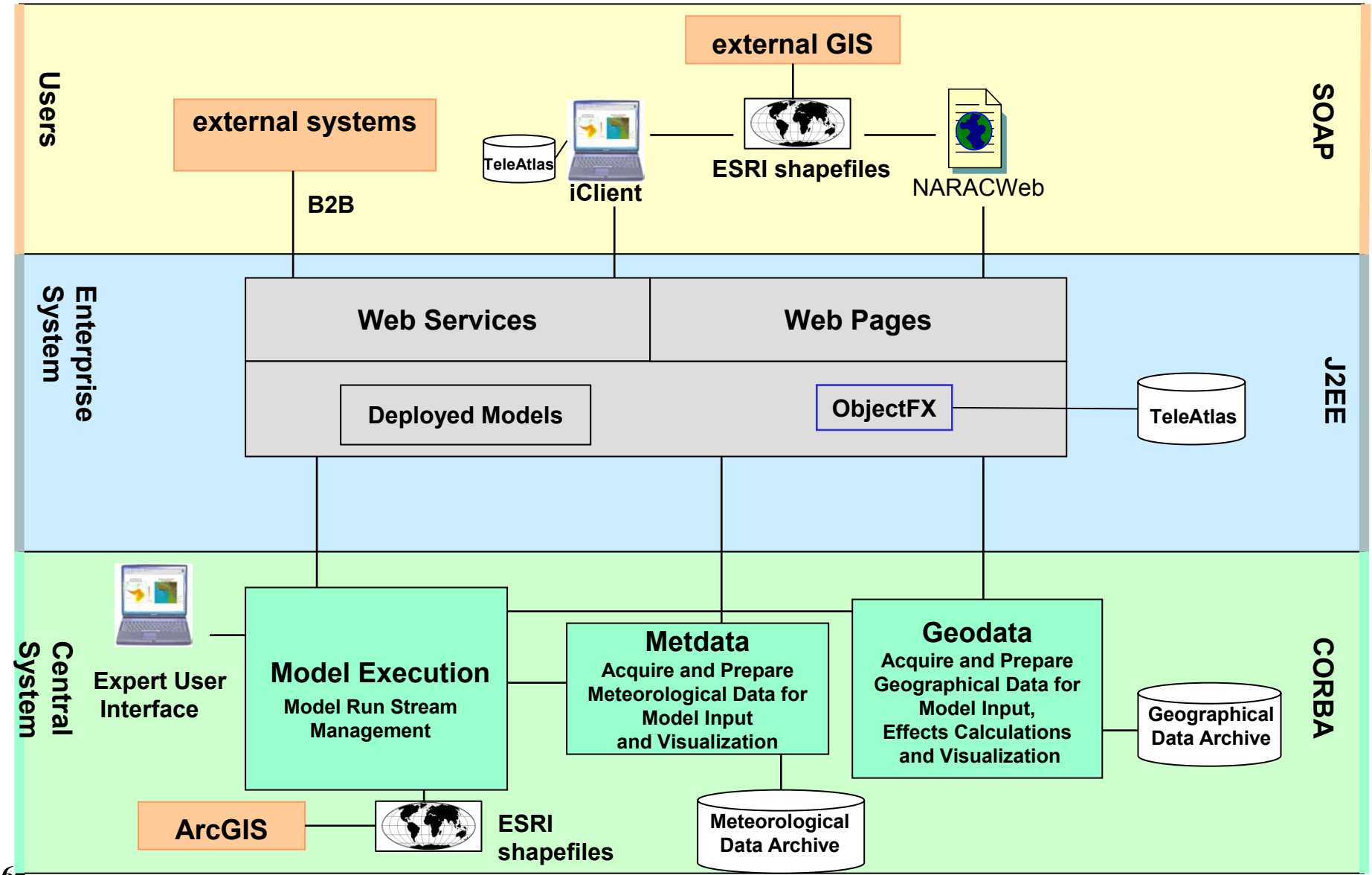
Component-based LLNL NARAC-IMAAC Computer Systems Support In-house and External Users



LLNL NARAC-IMAAC "Wiring Diagram"



NARAC-IMAAC System Architecture and Geospatial Data



On-line Databases: Geographical and Meteorological

- Geographical Data
  - —Terrain elevation: Global (NGDC 10 km resolution; USGS 1 km; NIMA 1 km, 100 m, 30 m) and U.S. (USGS 30 m)
  - —Land characteristics: Global (ORNL 1 km GLCC) and U.S. (USGS 200 m LULC & 30 m NLCD)
  - —Population data: Global (ORNL 1 km LandScan) and U.S. (Census Bureau blocks)
  - —Maps: Global (NIMA VMAP & ADRG), U.S. (GDT, Census Bureau TIGER, USGS DRG, USGS DOQ)
- Real-time Observational and Forecast Meteorological Data
  - — Global surface and upper air observations (Air Force, NOAA)
  - — Site observation networks (DOE & DOD facilities)
  - — Regional observation networks (MESOWEST, NOAA)
  - — Global forecast model data: NOAA (AVN/GFS), U.S. Navy (NOGAPS)
  - — North America forecast model data: NOAA (Eta, RUC)
  - — Regional forecast model: U.S. Navy (COAMPS)

Access to geographical and meteorological databases is fully automated, allowing real-time access for any location in the world

On-line Databases: Material Properties and Effects

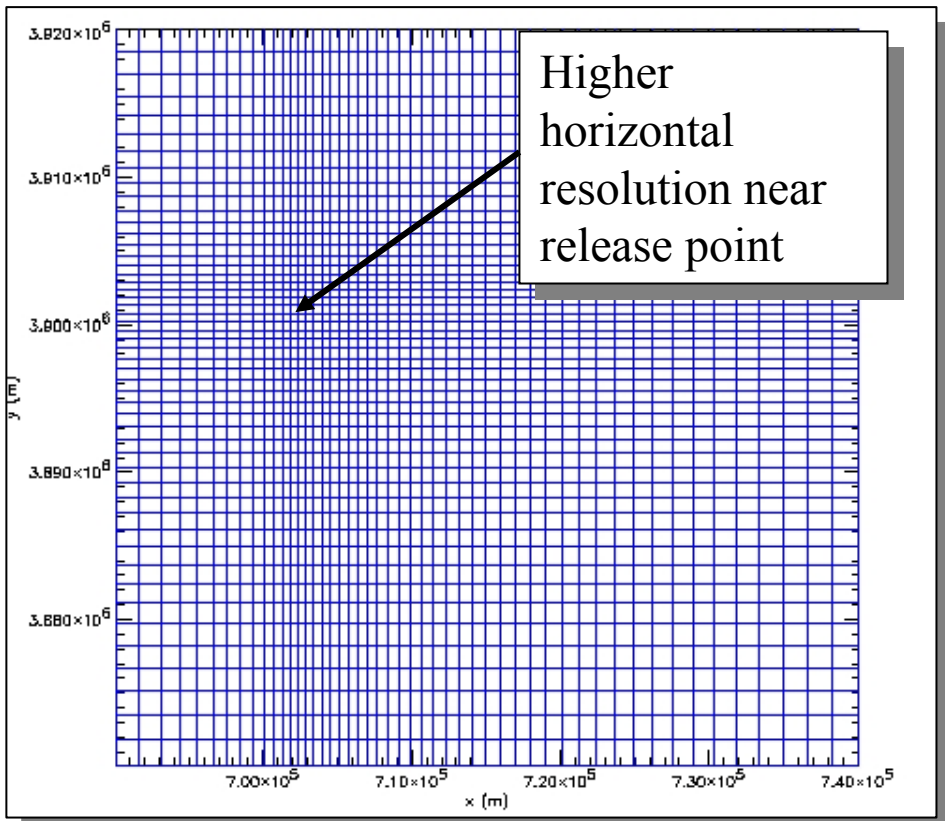
- Source material properties and decay rates
  - Radionuclide decay chains
  - Industrial chemicals
  - Chemical and biological agents

- Health Effects and Protective Actions
  - Radionuclide dose factors for inhalation, air immersion, and ground exposure modes
  - Radioactive dose protective action guides: EPA PAGs
  - Industrial chemical exposure limits : ERPG, TEEL, AEGL
  - Chemical and biological agent severe and lethal dosage levels

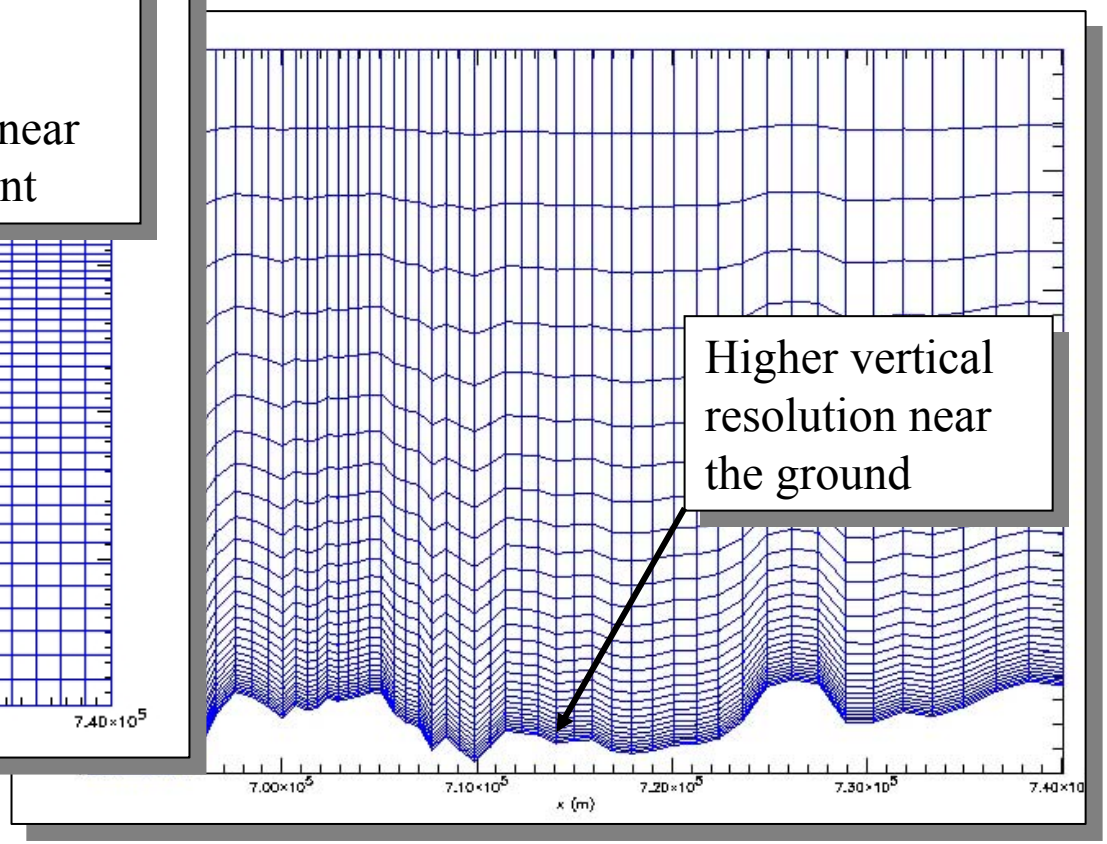
Appropriate action guides, exposure limits and health effect levels are automatically placed on all NARAC products

NARAC Model Grids (GridGen)

- **Variable-resolution model grids allow for more accurate simulations in areas of interest and faster calculations (because lower resolution is used in other areas)**
- **A continuous lower boundary provides for more realistic treatment of terrain effects**

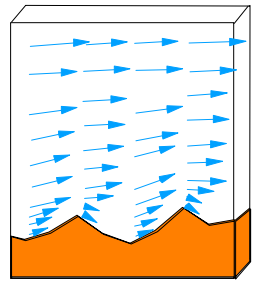


Horizontal plane



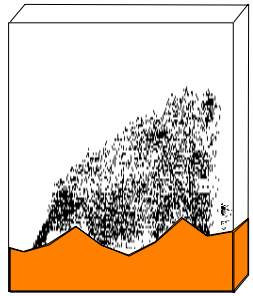
Vertical plane

ADAPT Meteorological Model Features



- Variable resolution grids with continuous terrain representation
- Multiple meteorological data sources:
  - — Observations: surface, tower, balloon, and profiler stations
  - — Forecast models: global and regional data (from NOAA or Navy) or in-house regional model forecast (NRL COAMPS regional model)
- Spatially-varying land surface characteristics
- Output meteorological data fields:
  - — Non-divergent wind field based on variational principal, finite-element spatial discretization and conjugate gradient solution method
  - — Temperature, pressure, humidity, and other scalar fields
  - — Precipitation
  - — Turbulence variables determined from meteorological and land-surface data using advanced similarity-theory turbulence scaling relationships and surface energy budget methods

LODI Dispersion Model Features



- Lagrangian stochastic (Monte Carlo) diffusion method
- Nested meteorological data grids
- Variable-resolution concentration and deposition grids
- Point, line, area, and Gaussian sources
- Aerosol mass-size distributions (log-normal or table)
- Multiple, moving, time-varying sources
- Momentum and buoyancy plume rise
- Decay and production of radionuclides in decay chains
- First-order decay of biological and chemical material
- Dry deposition (from gravitational settling velocity and deposition resistance)
- Precipitation scavenging (from aerosol size and spatially-varying precipitation rate)
- Multiple, moving receptors
- Output options: Air concentration, time-integrated concentration, ground deposition, integrated ground exposure, time series of concentration and exposure
- Post-processing options: Air immersion, inhalation, and ground exposure dose (combined pathways, TEDE), affected population, health effects (ERPG, TEEL, AEGL, LCT), recommended protective actions (EPA PAG)

For more information see

http://narac.llnl.gov